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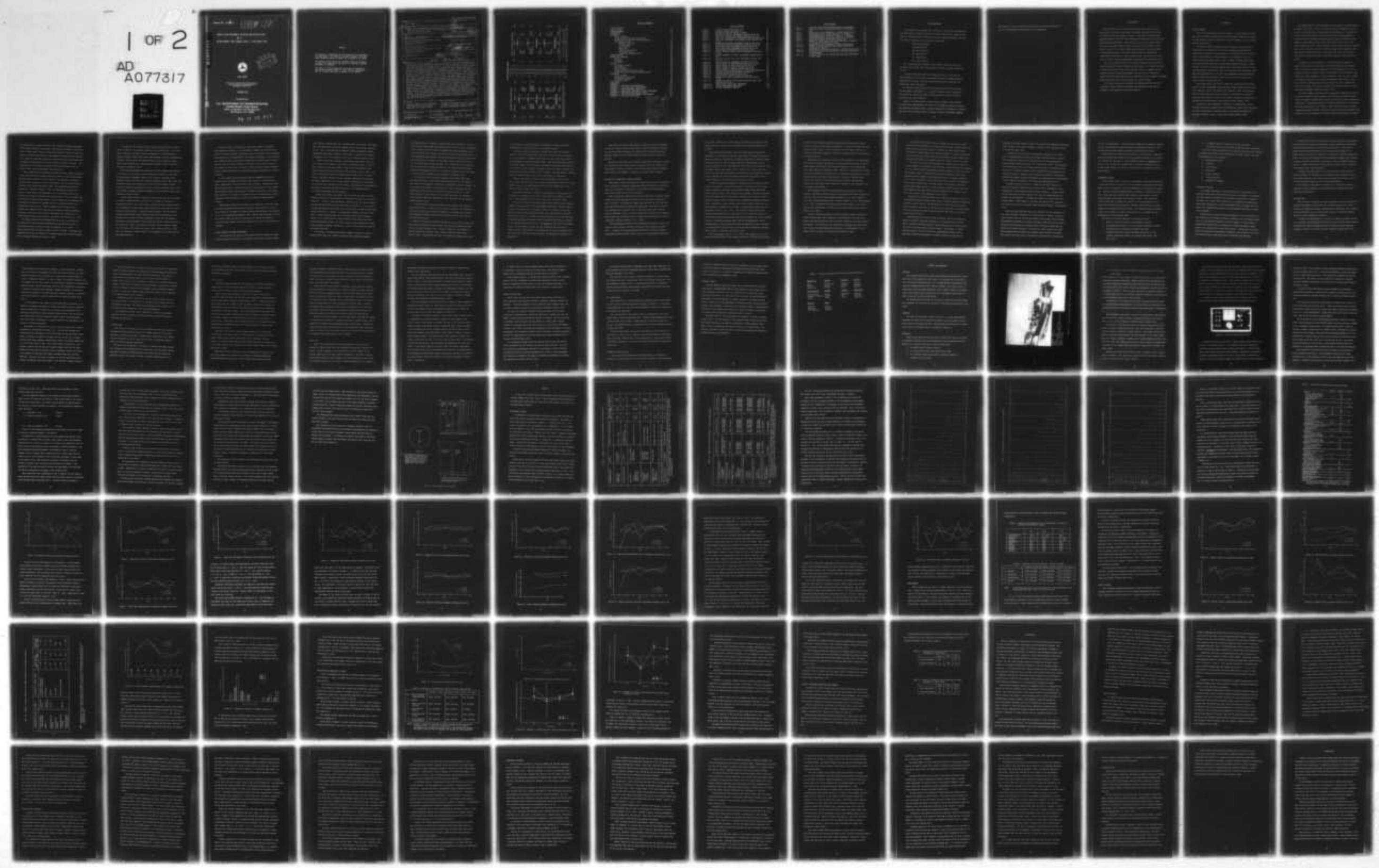

Report No. CG-D-85-78

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CHANGE IN CREW PERFORMANCE, PHYSIOLOGY AND AFFECTIVE STATE DUE TO MOTIONS ABOARD A SMALL MONOHULL VESSEL; A PRELIMINARY STUDY

FINAL REPORT

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DECEMBER 1978

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16. Abstract

A preliminary study was conducted with six experienced male Coast Guardsmen and a small monohull vessel (95' Coast Guard Patrol Boat) to evaluate the feasibility of a proposed experimental paradigm as well as the sensitivity of an array of performance, physiological and affective state measures to vessel motions and motion sickness. Performance measures (e.g. Navigation Plotting, Critical Tracking, Visual Search, Complex Auditory Monitoring, Grammatical Reasoning, etc.), physiological measures (e.g. motion sickness severity, stress hormone excretion, urine output and specific gravity), and affective state measures (e.g. mood dimensions) were sampled continuously for eight hours each day for three consecutive days. All variables were compared between control (dockside, engines running) and steaming conditions (four-hour octagonal steaming patterns were repeated twice each eight hour day). Results show all physiological measures examined to be sensitive to the influence of vessel motions or motion sickness. Motion sickness severity was found to rise and fall depending upon the encounter direction of the vessel to the movement of the primary swell; steaming courses with head or bow seas produced significantly greater degrees of illness than did courses possessing stern or quartering seas. Vessel motions led to significant increases in crew fatigue and changes in concentration. Some performance tasks (e.g. Navigation Plotting and Visual Search) were degraded at sea despite significant learning effects observed while others were not. Recommendations regarding experimental design for impending vessel motion experiments are presented.

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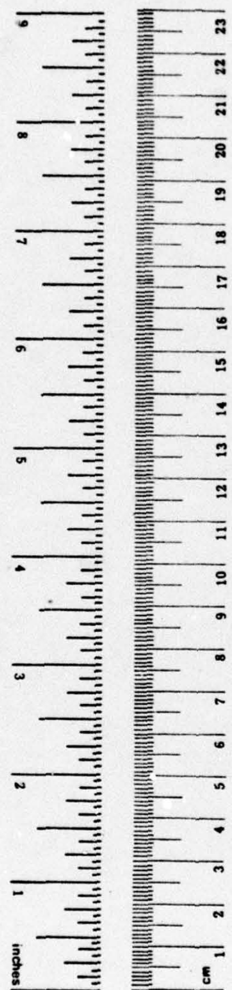
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

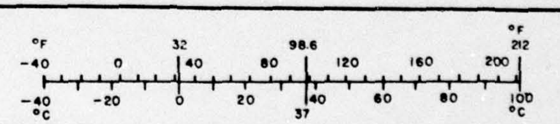
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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MKC Richard Zehrung

EM1 William Mears

BM3 Joel Whitfield

SN Robert McGill

SN Bruce Holton

FN Clayton Bentley

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INTRODUCTION

During the Spring of 1978 the United States Coast Guard, with the cooperation of the United States Navy, performed an operational evaluation of three very different classes of vessel; a 378' WHEC (Coast Guard High Endurance Cutter); a 95' WPB (Coast Guard Patrol Boat); and an 89' SSP (Navy Semi-Submersible Platform). These vessels vary not only in size, speed, endurance and possible mission profile, but react quite differently with respect to pitch, roll, heave, surge and sway frequency and acceleration in equivalent sea states. The Coast Guard and Navy are particularly interested in the effects of those vessel motions, characteristic to each class of vessel, upon crew performance, physiological and affective state.

Due to some conflict within the literature regarding the influence of vessel motion upon human performance and physiology, a preliminary study was performed using the 95' WPB, a small monohull vessel, to examine both the feasibility of the proposed experimental protocol prior to conducting research with the three vessels and the sensitivity of the proposed performance, physiological and affective state measures to vessel motion.

This report presents and discusses the findings obtained from this preliminary study and makes recommendations regarding the experimental designs for two subsequent multi-vessel studies.

BACKGROUND

MOTION SICKNESS

Very low frequency whole body motion below 1 Hz has significant influences upon a variety of physiological and psychological functions of humans. The most dramatic and well known reaction to such movement is that of motion sickness (kinetosis).

The extent of motion sickness incidence related to various modes of transportation is determined in part by the frequency and acceleration response of the vehicle to its environment, the susceptibility of the individual, and the amount of recent exposure of the passenger or crew to a similar motion environment (Money, 1970). Studies involving small marine craft have found the incidence of frank motion sickness (emesis) to range between 11 and 70% of the crew depending upon the severity of the sea state (Holling, McArdle, and Trotter, 1944; Tyler and Bard, 1949; and Llano, 1955). Emesis was experienced by 15 to 60% of the passengers aboard ships making winter crossings of the Atlantic Ocean during the first few days of the crossing (Chinn, 1956; Chinn, 1963).

From these studies, and others in which the susceptibility of various animals has been investigated (Chinn and Smith, 1955; Desnoes, 1926; De Wit, 1957; McEachern, Morton, and Lehman, 1942; Pozerski, 1921; Tyler and Bard, 1949), it would appear that motion sickness is inevitable for unadapted individuals who possess an intact and functional vestibular system given an appropriate force environment and sufficient exposure (Money, 1970).

Although the above hypothesis is difficult to substantiate, results obtained from motion sickness history questionnaires indicate that the malady is widely experienced; approximately 90% of the populations sampled had previously suffered illness in motion environments (Reason, 1967).

The symptomatology of motion sickness has been recently reviewed (Reason and Brand, 1975; Money, 1970). From these reviews and independent investigations by many physicians, physiologists and psychologists, it appears that the onset of motion sickness is often associated with the development of facial pallor, cold sweating, nausea and emesis (Clark and Graybiel, 1961; Crampton, 1955; Desnoes, 1926; De Wit, 1953; Fields, 1942; Flack, 1931; Gibson, Manning and Cohen, 1943; Gillingham, 1966; Graybiel, Kennedy, Knoblock, Guedry, Hertz, McCleod, Colehour, Miller and Fregly, 1965; Hemingway, 1944; Maitland, 1931; McEachern, Morton and Lehman, 1942; Money, 1959; Schwab, 1954; Taylor, Johnson and Sellers, 1960; Tyler and Bard, 1949; Whiteside, 1965).

In addition to the reliability of the above signs and symptoms, a sequential pattern of onset has been observed (Hemingway, 1944; Crampton, 1955); cold sweating and pallor generally precede nausea which in turn is followed by emesis. However, there are exceptions. Some individuals, upon exposure to highly provocative force environments, reach the stage of emesis so rapidly that nausea is not encountered (Maitland, 1931; Loftus, 1963). There are also individuals who either are unable to vomit, although they suffer acute nausea, or who fail to exhibit the nausea syndrome and associated emesis altogether (Reason and Brand, 1975).

For these reasons, and because other pathological conditions are apt to manifest the same or similar symptoms, sole reliance upon these "cardinal" signs and symptoms in diagnosing the onset and severity of motion sickness is insufficient. Fortunately additional indicants are available to substantiate the onset and severity of the illness. These "other" indicants, although possessing greater individual variability, serve not only to substantiate the diagnosis of motion sickness but offer more precision in scaling the degree

of sickness within a given individual (Wiker, Kennedy, McCauley and Pepper, 1979; Kennedy, Tolhurst and Graybiel, 1965; Miller and Graybiel, 1970; Wood, 1970). These "lesser" indicants range from changes in affective state (e.g. anxiety, depression and apathy) to development of gastrointestinal symptoms (e.g. epigastric awareness, burping and increased desire to move bowels) and to changes in neurological state (e.g. headache, dizziness, vertigo). For a complete list of all signs and symptoms which have been found useful in motion sickness severity assessment see Appendix (F).

Navy scientists have successfully developed a motion sickness symptomatology questionnaire and scaling system in an effort to find an experimental end point which provides a reliable measure to be employed in vestibular research while concurrently sparing test subjects from the rigors of emesis (Graybiel, Wood, Miller and Cramer, 1968). This methodology encountered success for a number of reasons. First, the questionnaire allowed the subject to make simple self assessments as to the existence and relative severity of an array of symptoms he was experiencing. Second, although there is individual variability with respect to onset and severity of symptoms, the development and remission of symptoms within an individual appeared to be characteristic and reliable. Finally, symptoms could be appropriately weighted and transformed into numerical scores which facilitated parametric statistical analyses of within subject experimental data (Graybiel et al., 1968; Kennedy, Moroney, Bale, Gregoire, and Smith, 1972; Wiker et al., 1979).

The symptom severity scaling methodology has proven its usefulness in the evaluation of motion sickness symptomatology experienced by normal and labyrinthine defective subjects aboard ship (Kennedy, et al., 1972). A similar approach has been used to assess the rate of change in symptomatology associated with onset and remission of sickness developed in the Slow Rotation Room at Pensacola (Reason and Graybiel, 1970).

Although man has confronted motion sickness since his earliest days of passive transport, its etiology continues to spur controversy. It is clear that a functional vestibular system is necessary for the development of nausea and emesis (Irwin, 1881; James, 1882; Kennedy, Graybiel, McDonough and Beckwith, 1965); however, the characteristics of the provocative stimuli which trigger sickness in a complex motion environment remain ill-defined (Guignard and McCauley, 1977).

Early studies suggested that incidence of motion sickness was related to the frequency of the vertical motions imposed upon subjects in laboratory motion generators (Alexander, Cotzin, Hill, Ricciuti, and Wendt, 1945; Alexander, Cotzin, and Klee, 1947; Johnson and Wendt, 1964). More recent and extensive analyses have demonstrated a definitive relationship between various frequency and acceleration levels of vertical sinusoidal motion and the incidence of emesis (O'Hanlon and McCauley, 1974; McCauley, Royal, Wilie, O'Hanlon and Mackie, 1976).

Further motion generator research found that pitch and roll, when added to vertical sinusoidal motion, did little to increase the frequency of vomiting (McCauley et al., 1976); hence, variations in heave characteristics were considered to be the primary contributing factor with regard to motion sickness incidence (MSI). It should be noted, however, that the heads of subjects participating in this study were restricted in movement by a supporting device to permit accurate assessments of head and body movement. Restriction of head movement in prior swing and aircraft studies has served to significantly reduce the incidence of motion sickness (Johnson, Stubbs, Kelk and Franks, 1951; Johnson and Taylor, 1961; Johnson and Mayne, 1953); thus, the incidence of motion sickness in the McCauley et al. study may have been underestimated.

From the evidence provided after nearly four decades of laboratory motion generator research, it is reasonable to suggest that the onset and severity of motion sickness is predicated upon the frequency and acceleration characteristics of the human head in the dynamic environment. That being the case, different motion environments produced by different classes of marine vehicles, via the vessel's response to external forces (e.g. wave action, swell direction, wind, etc.) dictated by inherent physical design characteristics, would be expected to provoke varying degrees and durations of motion sickness.

If the frequency and acceleration profiles responsible for motion sickness can be thoroughly identified, naval architects could then avoid vessel designs which elicit provocative motion stimuli. Additionally, ship operators may be able to monitor the motion characteristics of their vessel and effectively select vessel speeds or encounter directions to the seaway which minimize or eliminate the incidence of motion sickness among crew and passengers, thereby reducing the need to seek effective pharmacological therapy.

Significant strides have been made in the laboratory to this end using ship motion simulators which produce relatively simple motions in one to three dimensions or degrees of freedom (O'Hanlon and McCauley, 1974; McCauley et al., 1976; Guignard and McCauley, 1977). Whether these findings are valid and reliable under real world conditions, which involve six degrees of freedom and more complex variations in motion, has yet to be satisfactorily examined.

MOTION SICKNESS AND HUMAN PERFORMANCE

Investigations with vertical motion generators have produced no significant postexposure decrements in performance tasks such as running through

sand, running a 60-yard dash, dart throwing, speed and accuracy rifle shooting, code substitution and mirror drawings after a twenty minute exposure period. Only a tracking task, the Mashburn Complex Coordinator, showed a significant postexposure decrement attributable to the motion environment (Alexander et al., 1945; Alexander et al, 1947; Johnson and Wendt, 1964).

Similar results were obtained in Slow Rotation Room (SRR) studies in which subjects were exposed to rotational environments between 1.7 and 10 rpms constantly for various numbers of days (Clark and Graybiel, 1961; Guedry, Kennedy, Harris, and Graybiel, 1964; Graybiel, et al., 1965). The results indicated that motion sickness, except during the act of emesis, failed to degrade performance in grip strength, combination lock opening, arithmetic computation, dial setting, Whipple Steadiness Test performance, card sorting, dart throwing and ball tossing. Nonsignificant fluctuations in performance scores were attributed primarily to the changing levels of motivation possessed by the test subjects.

Abrams, Earl, Baker, and Buckner (1971) reported the effects of simulated sea motion upon the performance of experienced sailors in a sea motion simulator. Subject's task performance, affective state and motion sickness severity were monitored during simulated sea states (SS) 0, 3, 4, 4½, and 5. Although vomiting was not observed until SS 4½, motion sickness incidence was greatest during SS 5. However, no performance decrements occurred in tasks such as target classification, turn count tests, sonar target detection, Doppler Tests, Revised Minnesota Paper Formboard Tests, memory tests and reading comprehension exams. The authors reported that performance on these tasks continued to improve, probably as a result of the practice provided by the repeated testing.

In an effort to establish habitability design criteria for a 2000 ton surface effect ship, Jex, O'Hanlon and Ewing (1976) assessed crewmember

performance using a 3 degree of freedom linear motion generator. The frequencies and accelerations investigated (0.2-2 Hz @ 0.5-1.0 g), predominantly in the vertical axis were found to interfere with motor performance tasks such as plotting, lock opening, writing and critical tracking capability. In a postexperiment questionnaire, the subjects reported that task interference was due mostly to the physical or biodynamic effects upon the ability to write, position the plotting apparatus, etc., rather than due to indirect motion effects such as nausea and vomiting. No significant effects were observed in sensorimotor tasks such as auditory vigilance, short term memory or tests of critical flicker fusion (Clement and Shanahan, 1974).

In contrast to most laboratory findings, field studies which have assessed the effects of more complex whole body motions upon performance, have shown that performance is significantly degraded by motion sickness. In an analysis of the effects of an antimotion sickness preparation upon the computational capability of men aboard a life raft, Brand et al. (1967) tested subjects on land and then in a floating life raft. The placebo-control subjects completed significantly fewer additions than the subjects using antimotion drugs.

A Russian study by Sapov and Kuleshov (1975) analyzed the effects of long term exposure of a ship's crew to actual ship motion. The influence of vessel motion upon three different categories of performance was examined. The performance variables were physical efficiency, mental efficiency and professional efficiency.

Physical efficiency was measured through the use of aerobic measures and static muscle strength tests while mental efficiency was evaluated through the use of mental arithmetic tasks, Landolts' Ring test, rearrangement of numbers encountered in tangled lines, tracking tasks and simple visual reaction times. Professional efficiency was measured by comparing the speed

of performance on tasks associated with professional specialities under experimental conditions with that of established "norms".

Data were collected during the six-week study under the following sequence: One week steaming under calm sea conditions within a sheltered bay; a second week of steaming outside the bay; and a final three weeks at sea immediately following the second stage. Significant decrements occurred in physical, mental and professional performance during the second stage of data collection while a general improvement was seen in both the mental and professional performance during the third stage. These improvements, however, generally remained below control levels established in calm waters.

Physical efficiency continued to decline throughout stages two and three. This continual reduction in physical efficiency was attributed to the chronic stress and fatigue associated with postural demands made by the constant rolling action of the ship.

The primary reduction in mental and professional efficiency was attributed not to a reduction in the rate of task completion (quantity of work) but to large increases in error rates (reduction in quality of work).

The results of the Russian study, using actual vessel motions, appear to conflict with the failure to find performance decrements in motion simulator studies. The reason for this apparent conflict is unclear at this point. While laboratory motion generators produce less complex motions than those encountered at sea, it is possible that the laboratory experiments have been investigating radically different force environments than those encountered in the aforementioned field studies. The severity of the motion was probably greater in the simulator studies, but the complexity and duration were greater at sea. Unfortunately no recordings of the force environments were made aboard the field study vessels; hence, any quantitative comparison is impossible.

Some manual performance tasks appear to suffer from direct biodynamic interference brought about by vessel motion. Whether cognition and perception are significantly degraded with vessel motion, or resultant motion sickness, appears to be in dispute when laboratory and field studies are compared.

Obviously a controversy will continue concerning the efficacy of laboratory simulation until a field study is conducted, with test vessels fully instrumented to record all motions, and then replicated using a laboratory motion generator programmed to simulate the recorded vessel motions.

PHYSIOLOGICAL CORRELATES OF MOTION SICKNESS

Physiological stress associated with vessel motions can be attributed to both the physical or postural demands placed upon the body due to accelerations in six degrees of freedom and to the disruption in physiological homeostasis brought about by motion sickness.

Most physiological indices that have been employed in laboratory stress research have been unsatisfactory predictors of the onset or severity of motion sickness. Cardiovascular changes such as pulse rate and blood pressure, when monitored during Swing Pole experiments, were found to rise or fall depending upon the subject and to some extent the stage of motion sickness (Hemingway, 1945). Similar findings were obtained in Slow Rotation Room studies that found additionally no significant alterations in electrocardiogram recordings (Graybiel et al., 1965).

Electroencephalogram (EEG) studies generally have failed to detect the onset of motion sickness (Cipriani and Morton, 1942; Lindsley and Wendt, 1944). Attempts at developing diagnostic EEG tests of motion sickness susceptibility for selection criteria proved to be unsuccessful (Tyler and

Bard, 1949). Chinn et al., 1950, however, did report an activation of the alpha state with a reduction in the dominant wave frequency during motion sickness.

Some physiological measures, aside from those generally considered symptomatic of the disorder, have been consistently encountered during both laboratory and field induced motion sickness circumstances. Oliguria (reduced urine production) has been repeatedly observed during periods of motion sickness (Graybiel et al., 1965; DeZouche, 1894; Oriel, 1927; Knoblock, 1965; and Taylor, Hunter, and Johnson, 1957). Taylor et al., 1957, found that urine output was lowest in subjects who suffered most from laboratory induced motion sickness; over 70% of the subject population experienced a 65% or greater reduction in urine production from control levels.

It has been argued that exposure to unusual motion environments could produce fluctuations in blood pressure which in turn would elicit a vasopressin response to stabilize blood pressure through reduced glomerular filtration rates (Share, 1969; Segar and Moore, 1968). Oliguria encountered during opticokinetically induced motion sickness, which involves no body movement, however, tends to discount such a hypothesis (Dichgans and Brandt, 1973). Furthermore, urine chloride levels do not change in their rate of excretion but are shown only to increase in concentration with motion sick individuals (Taylor et al., 1957). This evidence further supports the hypothesis that reductions in urine output, and a concomitant increase in urine specific gravities associated with motion sickness, are due to increased release of antidiuretic hormone (ADH) from the neurohypophysis. Recent experimentation in the laboratory has directly demonstrated rapid increases in serum ADH levels with the onset of motion sickness (Evansmann, Gotteman, Uhluh, Ulbrecht, von Werder, and Scriba, 1978).

Some investigators (Taylor et al., 1957), have suggested that within-subject serum ADH levels, urine production rates or urine specific gravities

would be useful objective predictors of the onset and severity of motion sickness in actual vessel motion environments. To date, no studies have been conducted which attempt to relate ratings of motion sickness severity in kinetotic environments compared to objective measures such as urine production or specific gravity.

Regardless of the mechanism involved in the increase of circulating ADH during motion sickness, the actions of this hormone upon the body are widely known (Verney, 1947; Share, 1961; Orloff and Handler, 1967; Grantham and Burg, 1966; Schwartz and Schwartz, 1967). ADH acts to inhibit water diuresis and elicits peripheral vasconstriction of arterioles and capillaries, as well as major thoracic arteries, which serves to increase or stabilize blood pressure via increase in the effective vascular volume. Additionally, cerebral and renal blood vessels dialate in response to the subsequent rise in systemic blood pressure.

Other hormonal changes have been observed with the onset of motion sickness. Laboratory studies using motion generators have found increases in excretion rates of both catecholamines (Graybiel et al., 1965; Colehour, 1965) and 17-hydroxycorticosteroids (17-OHCS) (Graybiel et al., 1965; Evansmann et al., 1978) in subjects who suffered from motion sickness. Air sickness has also been demonstrated to elevate serum 17-OHCS levels aboard aircraft (Dahl et al., 1963).

The most convincing evidence for motion sickness induced elevations of stress hormones comes from a comparison of catecholamine excretion rates between labyrinthine defective (LD) and normal subjects in the same kinetotic environment. The LD subjects, who experienced no significiant motion sickness, failed to produce significant elevations in catecholamines, but the normal subjects experiencing kinetosis did (Colehour, 1965).

It should be noted that the above findings were obtained in largely angular motion environments (e.g. slowly rotating rooms, spinning chairs and aerobatic aircraft) which primarily stimulate the semi-circular canals. Experiments in which subjects were exposed primarily to linear accelerations in the vertical plane, which stimulate the otoliths, failed to produce any significant elevations in epinephrine excretion rates (Jex, et al., 1976).

The use of both urinary catecholamine and 17-OHCS excretion rates as relative gauges of both physical and emotional stress has been widely accepted for use in within subject experimental designs (von Euler, 1965a; von Euler, 1965b; Mason, 1968). Catecholamines which are synthesized in the brain, sympathetic nerve endings, the medullary portion of the adrenal gland and other sites of chromaffin tissue, have been found to increase in response to extraordinary stresses such as thermal burns, cold, hypoxia, childbirth, matriculation exams, periods of strong emotional reactions such as fear and during moderate exercise (Goodall, Stone and Haynes, 1957; LeBlanc, 1961; Levi, 1965; Sundin, 1958; Pekkarinen et al., 1961).

Elevations in catecholamine secretion rates permit muscular activity to be sustained through increased cardiac output, increased pulmonary ventilation, elevation in blood glucose, and redistribution of the body's blood supply from nonessential areas such as the skin, mucous membranes and viscera during periods of stress to tissues of greater survival importance (e.g. skeletal musculature and brain).

Redistribution of the blood supply to skeletal muscles increases the amount of metabolic substrates necessary for increased muscular activity while concurrently removing metabolic waste products such as carbon dioxide and lactic acid which promote muscular fatigue. Furthermore, to insure adequate substrate levels in the blood, catecholamines inhibit insulin secretion, potentiate glycogenesis in skeletal muscle and stimulate the

breakdown of adipose tissue to release free fatty acids (Bueding and Bulbring, 1964; Celander, 1954; Korner, Chalmers, and White, 1967; Kosterlitz, 1968; Porte and Williams, 1966).

In addition to the promotion of physiologic endurance as described above, learning behavior and mental efficiency have been found to improve after epinephrine secretion was increased with nicotine administration (Frankenhaeuser, Myrsten and Post, 1970; Bovet-Nitti, 1965). These improvements, which may be due to increased vascular supply to the brain and activation of the reticular formation, were correlated with elevations in catecholamine secretion. However, other studies have reported no significant correlations between vigilance performance and epinephrine and norepinephrine release (O'Hanlon and Horvath, 1973; Bloch and Brackenridge, 1972).

Increased urinary excretion of 17-OHCS also has been related to a variety of stressful conditions (e.g. tissue injury, inflammation, acute hypoglycemia, electroconvulsive shock and acute anxiety). Stressors which elevate glucocorticoid levels appear to act upon the adenohypophysis and possibly the hypothalamus, to increase the release of adrenocorticotropic hormone (ACTH). ACTH produces or initiates the release of the glucocorticoids from the cortex of the adrenal gland (Braun and Hechter, 1970; Kendall, 1971).

Glucocorticoids have been found to be essential for the maintenance of life under stressful conditions for a wide variety of animals. Release of these steroids serves to elevate and maintain blood glucose levels through gluconeogenesis (formation of glucose from amino acids and free fatty acids produced from mobilization of adipose tissue and protein catabolism) and deposition of hepatic glycogen. In addition to their effects upon carbohydrate metabolism, glucocorticoids increase blood pressure by producing fluid shifts from body cells to intravascular spaces and by prolonging the

actions of catecholamines. Glucocorticoids antagonize the enzymatic degradation of catecholamines; thereby permissively enhancing the actions of catecholamines upon the peripheral vasculature (Deane and Rubin, 1964).

Catecholamines and glucocorticoids react to a wide variety of physiological and psychological stimuli which are generally considered to be stressful. Whether the reactions of these biochemical agents are directly beneficial in the defense from or adaptation to noxious environments requires further study; however, the utility of such measures as indices of stress is well accepted.

PERFORMANCE TESTING

In the present study, a battery of psychological tests was administered to assess the effects of motion on such psychological processes as short-term memory, pattern recognition, sentence comprehension, and mathematical reasoning. These are objective measures which are related to successful performance in many important shipboard jobs, especially with regard to bridge watch-standing, surveillance, and search and rescue. Seven tasks were selected which were considered both relevant to the performance areas of concern and of sufficient reliability, validity, and sensitivity to detect changes in performance produced by stress. The candidate measures ranged in character from simple to complex, from operational to abstract and from machine-paced to subject-paced tasks.

The battery of selected tasks met the following criteria:

1. Tapped a variety of cognitive and psychomotor skills.
2. Had operational relevance, i.e. had similar components to those occupational duties normally performed aboard ship.
3. Possessed sufficiently good statistical reliability so that repeated testing was possible (see Kennedy and Bittner, 1977; Rose, 1974).

4. Possessed sufficient sensitivity so that they would be capable of manifesting stress induced performance decrements.

Tasks were selected according to an analysis of prior studies, and based on ongoing work by Rose (1978) and Kennedy and Bittner (1978). The seven tasks employed in this study were:

1. Navigation-Plotting
2. Tracking
3. Letter Search
4. Spoke Test
5. Complex Counting
6. Code Substitution
7. Grammatical Reasoning

Navigation Plotting

The primary requirement of any ship, military or nonmilitary, is to navigate safely and accurately from one position to another. To accomplish this goal requires the operation of electronic and mechanical navigation equipment (e.g. loran, radar, sextant, etc.), mathematical reasoning and operational manipulation of plotting equipment such as triangles and dividers in the attainment of geometric and trigonometric solutions to navigational problems.

Navigation and position plotting performance is not only important in the satisfaction of strategic operational missions, but it provides information to bridge personnel regarding relative movement of other vessels or navigational hazards which is necessary for collision avoidance, target pursuit and interception or escape from pursuers. Furthermore, such skills enable utilization of environmental information (e.g. current set and drift, true wind velocity) required for safe and effective ship handling.

To assess the effects of vessel motion upon these skills, a navigational plotting task was developed using standard plotting equipment and procedures typically employed aboard all Coast Guard and Navy ships. The task was subject-paced and required subjects to plot the relative movement of a target vessel using a pair of triangles, a compass and a standard maneuvering board. In addition to plotting the relative movement, subjects were required to employ arithmetic and geometric reasoning, as well as nomogram interpretation, to compute the relative course, speed and closest point of approach of successive target vessel movements.

Although the present task did not involve the more complex types of plotting problems, it did employ all of the basic skills required to solve more advanced problems. The task was easily mastered with practice, yet it involved sufficient complexity to be considered demanding.

The navigation plotting task is composed of a variety of perceptual, cognitive and motor components, including numerical computation, spatial reasoning, and dexterity.

Tracking Task

With the need for accurate and timely navigation, nearly every aspect of shipboard performance requires some form of manual operation of a control system (e.g. navigation, gunnery, communications, engineering, etc). Degradation of performance in any of these areas can have a significant negative impact on overall shipboard performance.

To assess such performance, it is useful to consider the human operator as a biological servo-mechanism which receives input from the sensory system, integrates the sensory information within the central nervous system and produces an output in the form of a motor response. Reevaluations of the

output accuracy by the operator are made in a consecutive manner. However, due to the delay in time between the input and output processes, this servo-mechanism (operator) is considered to be intermittent or discontinuous in nature. Tracking performance, or time on target, is therefore dependent upon the dynamics of the target as well as the functional integrity of the operator's sensory systems, central processing capability, and neuromuscular capacities to provide an accurate motor response. Tracking performance is frequently employed as a measure of the human operator's transfer function, or effective time delay between the incoming stimulus and the outgoing response (Rose, 1974).

If the dynamics of the target can be systematically controlled, it is possible to evaluate the effects of various environments upon the operator's effective time delay. In addition to producing direct biodynamic interference in the operator's motor response characteristics, ship motions also may distort visual sensory systems and higher nervous center processing which could lead to decrements in tracking capability via lengthening of the operator's effective time delay.

Many forms of tracking exist for use in such evaluations (e.g. pursuit, compensatory, subcritical, critical, etc.). The Critical Tracking Task possesses several advantages over the other forms for this particular study. First, the subject is required to compensate for, or null out, an unseen evasive target whose dynamics systematically exceed his tracking capabilities in a very short period of time. This allows several trials within a few minutes. Second, the fact that the target is unseen, with only the error between the target and the subject's pointer displayed, reduces the ability of the subject to anticipate the target's movement making the task more difficult. Finally, the critical tracking, or critical instability score provides information concerning changes in the operator's transfer function

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as well as the dynamic limits of control operation in the form of an oscillation bandwidth limit for the particular subject and the conditions existing during his performance.

Letter Search

The Neisser Letter Search Task was selected to evaluate the influence of vessel motion or motion sickness upon one's ability to locate a specific target pattern within a complex visual stimulus background.

Letter Search, which requires location of a target letter within a string of alpha characters, has previously been employed in investigations of visual search behavior (Neisser, 1963; Neisser, 1967). These studies found that search times for strings of alpha characters, which did not contain a prespecified target were considerably greater than search times obtained for strings which contained a target. This finding implied that there was some form of search hierarchy involved which required complete satisfactión prior to allowing a subject to conclude that the target did not exist within a given string. Furthermore, the hierarchy was believed to be dynamic in that search times were equivalent between rounded and angular or linear target patterns (e.g. Q and Z).

Although the form of the search hierarchy remains to be determined, initial search times were found to be proportional to the number of letter targets sought within a given alpha string. After extensive practice, however, the proportionality was lost and subjects were able to search for up to ten target letters at the same rate as a single target (Kaplan and Carvellas, 1965; Neisser 1967).

These results lead to the belief that the phenomenon of visual search could be accounted for in terms of two levels of information processing, serial and parallel processing. The more primary serial processing mode

requires a subject to evaluate a visual stimulus using his search hierarchy (a rank-ordered visual feature analysis). With extensive practice, however, both short and long term memory processes come into play and the subject is able to exercise a specific search hierarchy for each target simultaneously, hence the term parallel processing.

Deterioration in Letter Search performance in well practiced subjects can be attributed to interference in a subject's memory processes requiring a shift from the more expedient parallel form of visual search to the serial form of processing. There also may be a disruption in the subject's ability to execute the search hierarchy itself in the cognitive areas of the brain, thus requiring parallel or serial processing at reduced rates. Finally, performance can be degraded in this task by a disruption in the quality of the sensory input which may alter previously established hierarchies and thereby require use of alternate and less practiced search strategies.

Reduction in the performance of this visual search task might be related to a decline in the ability of shipboard personnel to visually detect aids to navigation in complex visual backgrounds such as coast lines. Lookouts and bridge personnel would have difficulty in distinguishing between and within vessel silouettes at sea and visual acquisition of persons or rescue vehicles in stormy seas may additionally be less reliable.

Spoke Test

Linked with the importance of target recognition is the ability of personnel to make accurate and timely judgments concerning the dynamics of a target. Spatial judgments are associated with functions located in, or strongly mediated by, the right cerebral hemisphere of the brain. Numerous investigations have been made throughout the years concerning not only types of performance specific to a particular cerebral hemisphere but the degree of

performance impairment associated with specific degrees of organic brain damage to each hemisphere.

One such study was performed using an Army intelligence test, the Trail Making Test (Manual: Army Individual Tests, War Dept.; The Adjutant General's Office, 1944), to investigate the degree of organic brain damage in neurological patients (Reitan, 1955). Results showed that not only did successful performance hinge upon subject alertness and concentrated attention, but that scores with numeric forms of the test were highly correlated with damage to the right hemisphere; the lower the score the greater the extent of damage (Reitan, 1958; Fitzhugh, Fitzhugh and Reitan, 1961).

The Trail Making Test was later modified to include a motor component to distinguish between visual and proprioceptive as well as cerebral contributions to the overall quality of performance (Graybiel et al., 1965); the modified version of the test was renamed the Spoke Test.

The Spoke Test requires subjects to move a pencil from a central circle to a peripheral circle which contains a number and return again to the central circle. This process is repeated for each of the thirty-two equidistant concentric peripheral circles in numerical order. When the numbers in the peripheral circles are randomly ordered, the subject must visually search the periphery and judge whether a given number is greater or lesser than the number sought. By subtracting the time required to complete the simple tapping task from that of the more complex search task, it is possible to obtain an indication of the processing time required by the right hemisphere to successfully complete the usual search and numeric comparisons. The difference score is less contaminated with variations in proprioception and neuromuscular capabilities between subjects and, therefore, is thought to be a more reliable indicant of disruption in central processing of spacial forms of information.

If vessel motion or motion sickness produces significant increases in the difference scores obtained with the Spoke Test, then spatial judgment capabilities of shipboard personnel could be expected to decline.

If the simple movement, or tapping task, shows significant time increases, then the ability of personnel to effectively manipulate multiple control panels in engineering control rooms, on radio or navigation equipment, etc., would also be expected to degrade under the influence of vessel motion.

Complex Counting Task

Aboard ship, long periods of sustained attention and utilization of short term memory are generally required of radarmen, sonarmen, lookouts and radiomen. To evaluate changes in these parameters under steaming conditions, an auditory complex counting task was selected (Kennedy and Bruns, 1975).

The task was originally conceived from observations of the varying abilities of technicians in a nephrology laboratory to monitor and count the number of drips produced from various numbers of kidneys. Later this complex, or multiple, mental counting task was adapted to a three light flashing display for investigations of sustained attention in high noise environments (Jerison, 1956; 1959). Although these experiments found decrements in counting performance, other subsequent studies found no decrement in noise environments; however, the maintenance of such performance was strongly associated with an increase in physiological costs.

In a comparison between visual and auditory forms of the test Kennedy (1971) determined that the auditory form was the most difficult. The auditory version was subsequently employed in an evaluation of three different aircraft penetrating a hurricane (Kennedy et al., 1972). Error percentages were found to be related to the degree of turbulence encountered; the greater the turbulence the larger the error rate.

The complex counting task is demanding even under ideal conditions and rarely produces error free performance when two or more tones (channels) are monitored (Kennedy et al., 1975).

Any reduction in the ability to sustain attention or to utilize short term memory would lead to significant errors in the mental monitoring of the quasi-randomly presented tones. If vessel motion directly or indirectly disturbs these processes, then shipboard tasks which rely heavily upon such processes would be expected to degrade.

Code Substitution

Code Substitution is a paper-pencil test developed in the early 1900's to select clerical workers and office personnel in industry. It currently enjoys widespread use, with some version employed in nearly every aptitude or intelligence test developed.

The form employed in the present study is an adaptation of the Otis (1939) digit to letter substitution task. Wechsler (1939) employed this task in WISC because he felt that it tapped elements of perceptual-speed and accuracy, am important dimension discovered in his prior factor-analytic work of human abilities.

The Code Substitution test was selected because of its historic use, face-validity, and the need to employ a test which is based upon perceptual-motor abilities. Additionally, it has similarities to several jobs related to shipboard personnel, i.e. radio room coding and decoding of messages and signalling.

Grammatical Reasoning Test

It has recently been shown that the time required to understand a sentence is largely dictated by its syntactical structure. Transformations

of the basic sentence structure (positive vs negative, true vs false, passive vs active) provide an intellectually demanding task which has good reliability, is sensitive to a variety of stressors and correlates reasonably well with intelligence tests (Baddeley, 1968).

AFFECTIVE STATE

The Mood Adjective Check List (MACL) and the Pensacola Motion Sickness Questionnaire (NAVSCOLAVNMED 6500/24C) were employed in the present study to assess changes in affective state precipitated by the stress and arousal resulting from exposure to high levels of ship motion. The Mood and Motion Questionnaire has been employed in numerous studies of the effects of mood shifts. Because of the interdependency of emotional arousal and physiological response, the assessment of emotions are an important element in understanding the state of the organism when subjected to harsh environmental conditions; particularly when precipitious vomiting is likely to occur.

The mood portion of the questionnaire was designed to measure ten dimensions of mood. For each dimension, three adjectives were selected which have been shown previously to be sensitive indicators of affect (Nowlis, 1965). Table 1 lists the dimensions and the adjectives used to measure them. The subject's task was to check the degree to which he experienced each affective state described by the adjectives.

TABLE 1. Affective Dimensions and Their Associated Adjectives

Aggression	Anxiety	Surgency	Elation
Angry	Clutched up	Carefree	Elated
Defiant	Fearful	Playful	Overjoyed
Rebellious	Jittery	Witty	Pleased
Concentration	**Fatigue**	**Sadness**	**Skepticism**
Concentrating	Drowsy	Regretful	Dubious
Engaged in Thought	Sluggish	Sad	Skeptical
Intent	Tired	Sorry	Suspicious
Egotism	**Vigor**		
Boastful	Active		
Egotistic	Energetic		
Self-Centered	Vigorous		

METHODS AND APPARATUS

SUBJECTS

Six subjects were selected among the existing crew aboard the 95' Coast Guard Patrol Boat employed in this study. All subjects were males (24±7.2 yrs; 1.77±.06 m; 74.09±10.01 Kg). In a pre-experimental questionnaire, all reported average susceptibility to motion sickness. All subjects were in good health, were not taking medication, had no chronic smoking or drinking habits and reported normal concern over their performance aboard ship, on school exams and in sporting activities.

No compensation was provided to the subjects except that regular duties were suspended for the period of one week to allow their participation in the study.

APPARATUS

The mess deck compartment aboard the WPB 95' is located approximately amidships and served as the testing environment for both dockside (control) and at-sea data collection periods. Some descriptive characteristics along with a photo of the patrol boat are presented in Figure 1.

PROCEDURES

Subjects were selected initially from the patrol boat crew on the basis of information obtained from a pre-experiment selection questionnaire (see Appendix A). The major selection criteria employed were:

a. No chronic motion sickness history

b. At least six months sea duty aboard the 95' WPB

c. Not presently taking medications; no habitual smoking or excessive use of alcohol.

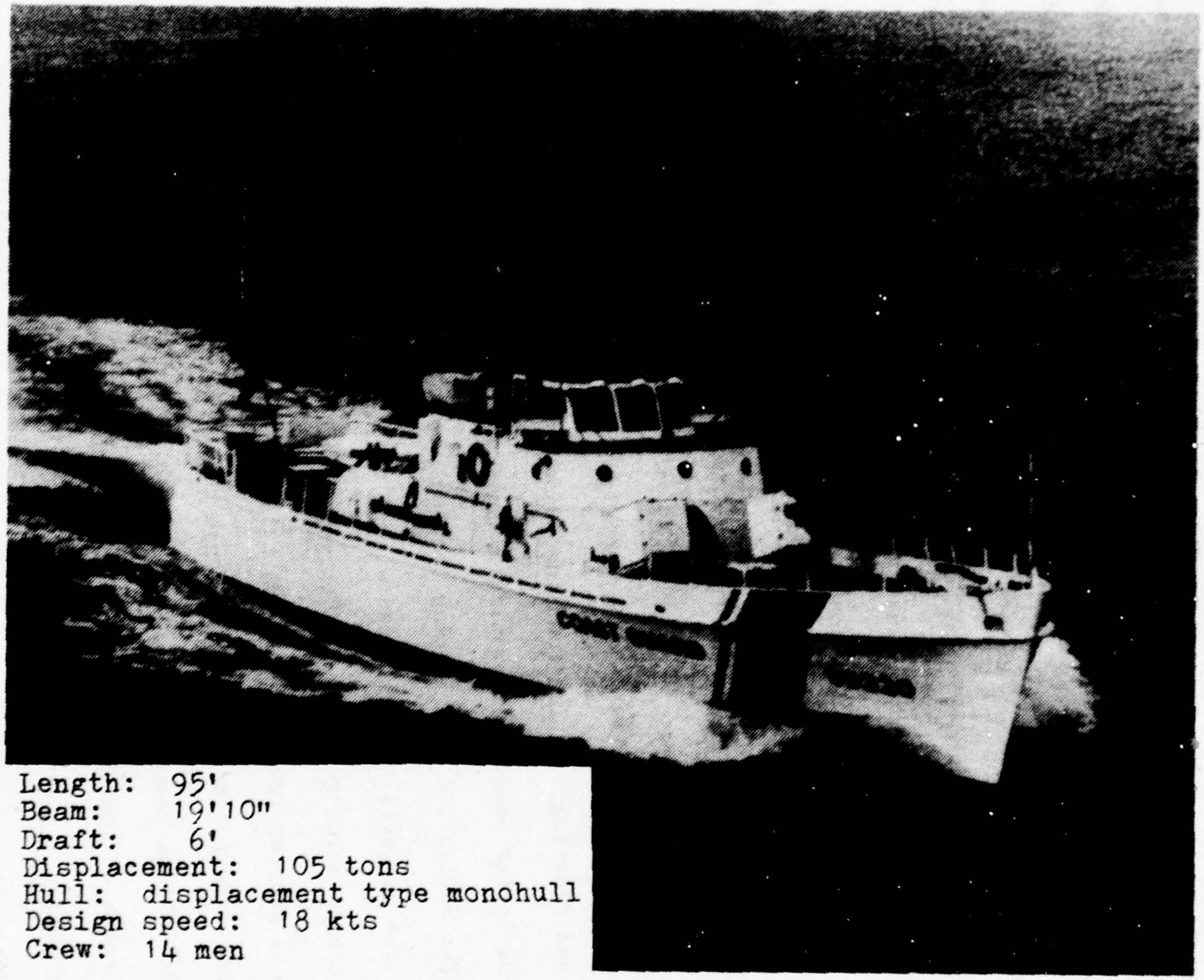

Figure 1. A typical Coast Guard patrol boat (95' WPB)

d. Willingness to give up liberty, during the course of the study (four days).

Test candidates received extensive training and practice on all performance tasks for a period of three days. Results obtained from the practice sessions were recorded and employed in the selection of the test subject population (one subject was unable to master the Navigation Plotting task and was subsequently deleted). Therefore, the final group of subjects employed in this study were relatively uniform with respect to education, motion sickness history, physical condition and task training.

In addition to performance task training, subjects were familiarized with motion sickness symptomatology and the mood adjectives employed in the combined mood and motion sickness symptomatology questionnaire (see Appendix B).

The performance task battery consisted of seven separate tasks: Navigation and Plotting, Complex Counting, Compensatory Tracking, Code Substitution, Letter Search, Grammatical Reasoning and the Spoke Tests.

The Navigation and Plotting task was a self-paced operational task in which the subjects were provided with a test sheet containing a series of relative position reports of a "target vessel". From these position reports subjects progressively plotted the relative movement of the target using a pair of 45 degree triangles, a compass and a standard maneuvering board (H.O. 2665-20). From these positions the relative course, speed and closest point of approach of the target vessel were plotted, computed and recorded on an answer sheet.

Subjects were given nine minutes in which to complete as many computations as possible. The results were scored for both total number completed, as well as their accuracy (percent correct).

The Complex Counting task (Kennedy and Bitner, 1978) required subjects to listen to three different tones (100, 900, and 1800 Hz) which were repeatedly presented in a quasi-random fashion with a Sony cassette tape recorder. Each subject was instructed to listen to and mentally keep track of the number of occurrences of the lower two tones. Upon reaching a mental count of four for either one of the two lower tones, the subject noted that event on a score sheet, reset his "mental counter" for that particular tone, and continued that procedure for a total of ten minutes. The task's score was based upon absolute errors in recording the quartets of the two lower tones.

Disruption in the Critical Tracking Task was investigated using a Systems Technology Inc. Mk 8A Critical Task Tester shown in Figure 2.

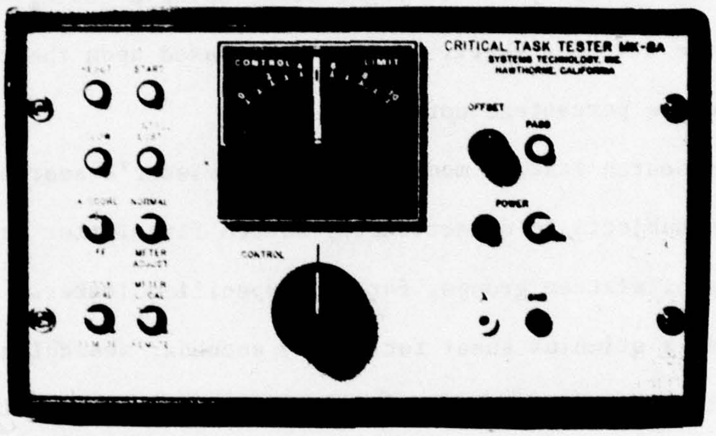

Figure 2. Critical tracking tester MK 8A

Subjects monitored and stabilized a highly reactive needle within the center of a meter type display. To accomplish this task, compensatory corrections against random needle movements were made via a free turning control knob located beneath the meter display. Eventually, as the needle was made increasingly unstable, the limit of the subject to effectively control or nullify the needle movement was reached and the needle disappeared,

ending the trial. The resultant score was displayed digitally indicating the critical tracking limit (λc), or oscillation bandwidth, at which the subject could no longer effectively track. Five trials were completed during each testing period. The median score was employed for analysis to minimize spurious biodynamic interference contributed by the jarring and pitching of the vessel at sea.

It should be noted that subjects were encouraged to take whatever measures were necessary to reduce direct biodynamic interference upon their tracking performance; thereby maximizing their tracking performance capability.

Code Substitution tests were administered to subjects for a period of two minutes during each testing period. During the allotted time, subjects substituted a numeric array for an alpha array using a coding matrix provided at the top of the stimulus sheet. Scores were based upon the total number of items coded and the percentage correctly coded.

The Letter Search task, a modification of Neisser's search task (Rose, 1974), required subjects to directionally search five-letter groups, arranged in four columns of sixteen groups, for a prespecified letter. Initially subjects scanned a stimulus sheet for twenty seconds, searching for a single preselected letter target. The first trial was followed immediately by the presentation of another stimulus sheet and instructions to search and locate letter groups which had either one of two specified letters. The second trial was followed by a third trial in which another stimulus sheet was scanned for letter groups which contained any one of four specified letters.

Scan periods for the Two and Four Letter Searches were increased to thirty seconds for each trial. The experimenter identified the target letter(s) prior to the initiation of each trial and timed each trial with a stopwatch. Subjects were instructed to mark the last group scanned at the

termination of each trial. Scores were based on total number of letter groups scanned per unit time.

For the Grammatical Reasoning task, subjects were provided a sheet of paper on which 32 sentences describing the order relationship of two letters, "A" and "B", were printed. The subjects had one minute to read and assess the validity of as many sentences as possible. The following are examples of these sentences:

1.	A precedes B - BA	"false"
2.	A does not follow B - AB	"true"
•		
•		
32.	B does not precede A - BA	"false"

Scores for the Grammatical Reasoning test were based on the total number of sentences correctly assessed in one minute.

The Spoke Test, a modification of the Trial Making Test (Reitan, 1955), consisted of a stimulus sheet on which a small center circle was surrounded concentrically by a series of similar circles which were equidistant from the center and evenly distributed along the periphery. Thirty-two numbers, 1-32, were randomly distributed throughout the peripheral circles. Upon the command to start, subjects were instructed to move a pencil point from the center circle to that peripheral circle containing the number "1" and return to the center circle. This process was repeated in numerical order as quickly as possible until the subject had located all 32 numbers. Upon completion of the task the subject notified the experimenter, who indicated the time for completion to be logged on the stimulus sheet.

Upon completion of the "experimental" run, a "control" run was timed in which subjects moved their pencil points from the center circle to a peripheral circle and back again repeatedly and in a clockwise manner as quickly as

possible until all 32 circles had been tapped. The "control" time was later subtracted from the "experimental" time to yield a "difference" time. Theoretically the difference time is a measure of central processing effort employed in the searching process.

Various forms of the test materials were appropriately randomized to eliminate unwarranted learning and other sequence effects. They were administered during a synthetic work cycle each hour.

Total void urine specimens were collected every two hours during each day's testing period (0800-1600). Each specimen was collected in a separate 24-hour urine specimen container, acidified with 2 ml of 6N HCl and stored for analysis until completion of testing each day.

Urine specimen volumes, specific gravities, total catecholamines and 17-OHCS levels were determined for each individual two-hour sample. Specific gravities were determined using a clinical hydrometer while total catecholamines were radioenzymatically assayed using a modified Passon and Peuler (1973) technique. All 17-OHCS levels were colormetrically determined using the Porter-Silber (1950) method.

During the days of testing all subjects ate the same diet in which no fluids or solid foods containing caffeine or alcohol were permitted. Restriction of stimulants and alcohol consumption was enforced 48 hours prior to commencing the experiment.

The morning meal was consumed each day approximately 1½ hours prior to testing and all subjects voided and discarded their morning urine just prior to 0800. Additionally, all subjects drank 240 ml of water, or highly diluted punch, every thirty minutes from 0800 to 1600 each day to insure proper hydration and adequate urine production for subsequent analyses.

Affective state and motion sickness symptomatology changes were assessed every thirty minutes during the data collection period. All subjects completed

a questionnaire which was a modification of both the Nowlis Mood Adjective Check List and the Pensacola Motion Sickness Questionnaire employed by Abrams et al. (1971) which is located in Appendix B. Mood dimensions were assessed according to Nowlis and Nowlis (1956).

Temperatures and relative humidity readings were made from a Mason's Form hygrometer placed within the testing compartment and were recorded every thirty minutes (see Appendix C for a graphical depiction of these data).

Sound decibel levels for each octave band were recorded within the testing compartment while underway at ten knots (see Appendix D for a plot of these sound levels).

The experimental plan was designed to assess the changes in performance, physiological and psychological state, within subjects exposed to a control condition (boat tied up dockside with engines running) and to the experimental condition (boat steaming at 10 knots in an octagonal pattern on the open seas). The collection of control data was preceded by one day of "mock" experimentation in which the subjects were told that the practice sessions had ceased and experimentation had begun. The intention of this procedure was to reduce the anticipatory or novelty stress often associated with the initiation of experimentation while at the same time providing an intense practice session to maximize performance of tasks prior to actual data collection.

The second day of data collection at dockside served as the control day for data analysis.

Experimental data were collected on two consecutive days following the dockside control day. The steaming patterns were initiated each day at 0800 at the same position seven miles southeast of the coast of Oahu, Hawaii, after a one-hour transit from port. The initial steaming course was selected each day in order to begin the steaming pattern with the vessel heading

directly into the primary swell. Upon selection of the initial course, 45 degree turns in a clockwise fashion were made every thirty minutes so that on the hour and half hour the vessel was steadied up on its new course steaming at ten knots. This procedure resulted in the vessel steaming two complete octagons each day. Figure 3 shows the steaming pattern and resulting course changes which occurred every half hour and the testing cycle associated with the course changes.

The steaming process continued non-stop until 1600 at which time the vessel returned to port where the subjects ate supper and rested until the next day's steaming.

Upon completion of the second day of steaming, subjects filled out experimental debriefing forms which provided the experimenters with subjective evaluations of the various performance, physiological and psychological measures and procedures. In addition the subjects were asked to rate which motions seemed to affect their performance and physical well being the most and the least (see Appendix E).

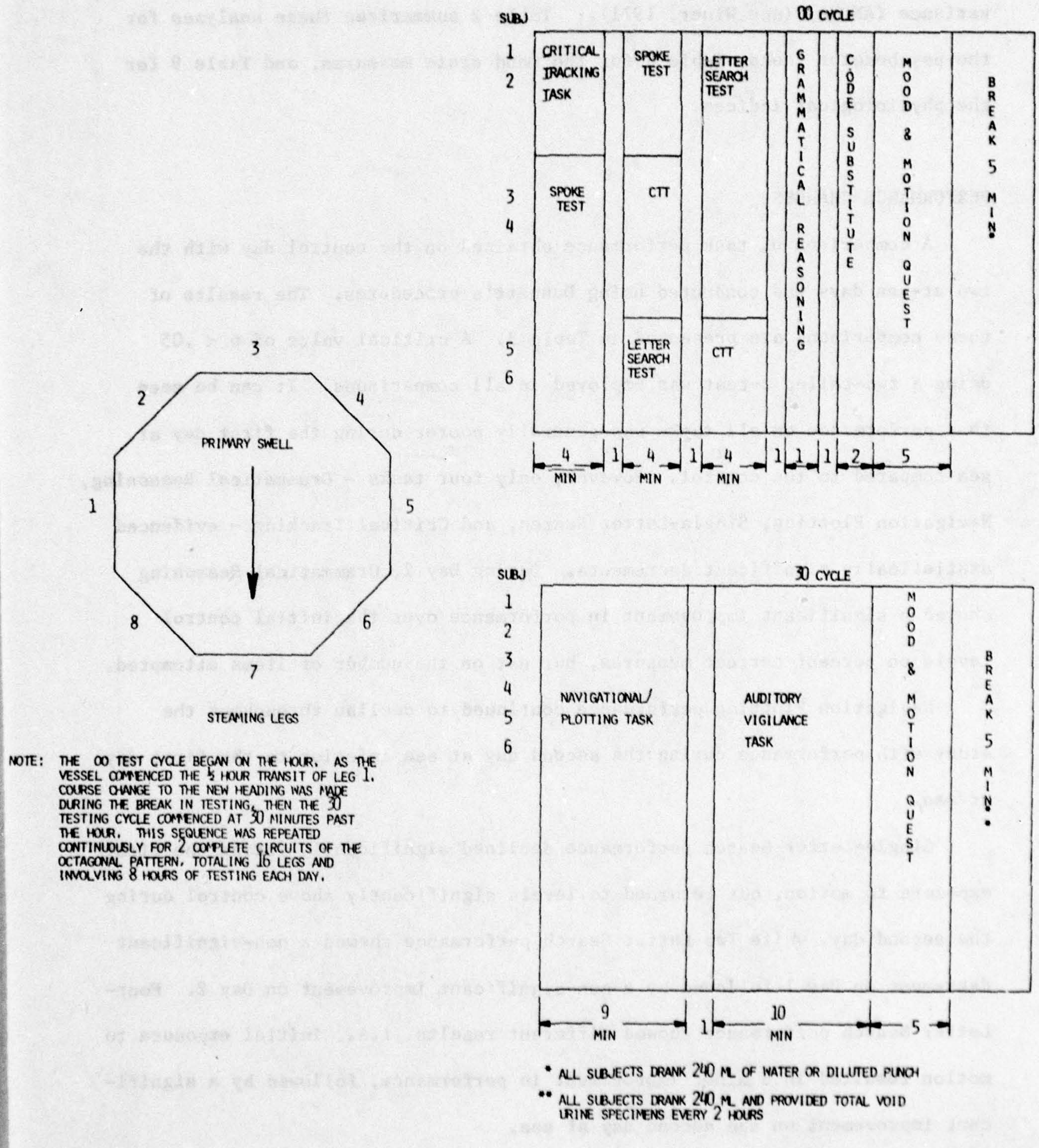

FIGURE 3. STEAMING PATTERN AND TESTING SEQUENCE

RESULTS

All data were collected and analyzed using a within subjects analysis of variance (ANOVA) (see Winer, 1971). Table 2 summarizes these analyses for the psychomotor tasks, Table 8 for the mood state measures, and Table 9 for the physiological indices.

PERFORMANCE CHANGES

A comparison of task performance obtained on the control day with the two at-sea days was conducted using Dunnett's procedures. The results of these comparisons are presented in Table 3. A critical value of $p < .05$ using a two-tailed t-test was employed in all comparisons. It can be seen that performance on all tasks was generally poorer during the first day at sea compared to the control. However, only four tasks - Grammatical Reasoning, Navigation Plotting, Single-Letter Search, and Critical Tracking - evidenced statistically significant decrements. During Day 2, Grammatical Reasoning showed a significant improvement in performance over the initial control levels on percent correct measures, but not on the number of items attempted.

Navigation Plotting performance continued to decline throughout the study with performance during the second day at sea inferior to the first day at sea.

Single-Letter Search performance declined significantly during the first exposure to motion, but returned to levels significantly above control during the second day, while Two Letter Search performance showed a non-significant decrement on Day 1 followed by a non-significant improvement on Day 2. Four-Letter Search performance showed different results, i.e., initial exposure to motion resulted in a minor improvement in performance, followed by a significant improvement on the second day at sea.

TABLE 2. Summary of Results Obtained from ANOVAs on Performance Data

PERFORMANCE TASK	METRIC	INFLUENCE OF VESSEL MOTION	MAIN EFFECTS		INTERACTIONS
			DAY	HOUR	D x H
Grammatical Reasoning	# Attempted		N.S.	N.S.	N.S.
	# Correct	No Sign. Change	N.S.	N.S.	N.S.
Navigation/Plotting	% Correct	Increased errors Changed with Time of Day	.01	.025	N.S.
Spoke Test	Time to Complete in Seconds (Log Transform)				
Control		Changed Over Time of Day	N.S.	.001	N.S.
Experimental			N.S.	.01	.05
Exp-Control			N.S.	.05	.01
Letter Search	# Attempted				
1 Letter	unit time	Performance Degraded	.01	.001	.001
2 Letter	unit time		N.S.	N.S.	.001
4 Letter	unit time	Performance Improved	.05	.01	N.S.
Complex Counting	Absolute Error				
Low Tone		Change with Time of Day	N.S.	.05	.05
Medium Tone			N.S.	N.S.	.05
Critical Tracking Task	λc (SQRT Transform)	Change with Time of Day	N.S.	.001	.05
Code Substitution	# Attempts	No Sign Change	N.S.	N.S.	.05

NOTE: Significant F ratios were converted to probability values and entered under the main effects or interactions column. Those values which did not reach the $p < .05$ level of significance are indicated by N.S.

TABLE 3. Comparison of Task Performance: Control versus At-Sea

	Control vs. Sea 1	Control vs. Sea 2	Sea 1 vs. Sea 2
1. Grammatical Reasoning			
(# Attempted)	Significant Decrement	N.S. Improvement	N.S. Improvement
(# Correct)	N.S. Improvement	Sign. Improvement	N.S. Improvement
2. Navigation Plotting			
(% Correct)	N.S. Decrement	Sign. Decrement	Sign. Decrement
3. Spoke Test (Time)			
Control	N.S. Decrement	N.S. Improvement	N.S. Improvement
Experimental	N.S. Decrement	N.S. Improvement	N.S. Improvement
Difference	N.S. Decrement	N.S. Improvement	N.S. Improvement
4. Letter Search (# Attempted)			
1 Letter	Sign. Decrement	N.S. Improvement	Sign. Improvement
2 Letter	N.S. Decrement	N.S. Improvement	N.S. Improvement
4 Letter	N.S. Improvement	Sign. Improvement	N.S. Improvement
5. Complex Counting (Error)			
Low Tone	N.S. Decrement	N.S. Improvement	N.S. Decrement
Medium Tone	N.S. Decrement	N.S. Improvement	N.S. Improvement
6. Critical Tracking Task (λc)	Sign. Decrement	N.S. Decrement	N.S. Improvement
7. Code Substitution (# Attempted)	No Change	N.S. Decrement	N.S. Decrement

NOTE: Dunnett's *t*-test was conducted to examine changes between control and treatment groups. A two-tailed test with $P < .05$ as a criterion was employed to determine the significance of the differences obtained (see Winer, 1971, p. 202 for rationale and details of this procedure).

Critical Tracking performance was significantly disrupted during the first motion day, but by Day 2 performance had begun to improve.

While task performance related to the introduction of ship motions produced by the daily steaming patterns of the WPB generally deteriorated during the first exposure day, an analysis of the second day's performance compared to control levels indicates just the opposite. Thus, of the seven tasks (13 measures), four (10 measures) indicate that performance had returned to or exceeded control levels.

Despite the small sample size, which generally limits the opportunity to demonstrate all but the most profound effects, 22 variables (13 performance, 6 stress and 3 mood) were analyzed using a Pearson product-moment coefficient of correlation technique.

The intercorrelation matrix for all variables recorded on the control day is presented as Table 4, while at-sea 1 data are presented in Table 5 and at-sea 2 data are presented in Table 6. It should be noted that with 6 df, a correlation would have to exceed .7067 to obtain a $p < .05$ and .8343 to obtain a $p < .01$. The correlation matrices are presented to indicate relationship and patterns of relationships which existed both during the controlled dockside testing and the two consecutive days at sea.

One must use caution in interpreting the results of such correlational analyses, as the probability of spurious relationships occurring solely as a function of chance increase directly with the number of correlations computed. It should also be pointed out that while the main effect of hours in our analysis was systematically related to the steaming pattern of the vessel during the two at-sea days, other time-based phenomena were inextricably involved with the testing/steaming patterns. Some of the more obvious were: time-of-day effects, subject biorhythms, fatigue, temperature, learning, and habituation.

TABLE 4. Intercorrelation of Control Scores of 22 Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. MSS																						
2. Emesis	.00																					
3. Urine Prod	-.19	.00																				
4. Urine SpG	.28	.00	-.99**																			
5. Δ% 17-OHCS	.02	.00	-.95**	.92**																		
6. Δ% CATs	-.15	.00	.86**	-.83*	-.73*																	
7. % NAVPLOT	-.36	.00	-.42	.39	.46	-.32																
8. Fatigue	.78*	.00	-.30	.42	.05	-.28	-.20															
9. Concentration	-.57	.00	-.00	-.11	.11	-.19	.06	.73*														
10. Skepticism	-.04	.00	-.40	.39	.37	-.37	.01	.48	.57													
11. Anxiety	.67	.00	.31	.41	-.13	-.19	-.48	-.15	.55	.24												
12. Tracking	.63	.00	-.34	.43	.11	-.34	.33	-.64	-.55	.04	.44											
13. Gram Reasoning	.28	.00	.23	-.20	-.33	.11	-.20	-.41	-.67	-.88**	.14	.18										
14. Complex Low Error	.27	.00	-.78*	.76	.69	-.79*	.18	.13	.14	.46	.26	.23	-.33									
15. Complex Med Error	-.18	.00	-.68	.61	.69	-.71*	.44	.35	.44	.45	-.17	-.03	-.49	.88**								
16. LS(1)	-.13	.00	.52	-.47	-.61	.38	.24	-.30	.03	.10	-.21	.36	-.18	-.37	-.26							
17. LS(2)	.54	.00	-.30	.38	.23	-.08	-.01	-.52	-.90**	-.54	.54	.45	.68	.02	-.27	-.41						
18. LS(4)	-.48	.00	.51	-.49	-.54	.36	-.04	.17	-.21	-.45	-.10	-.14	.49	-.67	-.53	.34	.07					
19. Spoke(C)	.60	.00	-.02	-.06	.03	-.29	.18	.69	.62	.17	-.42	-.28	-.08	-.23	.02	.04	-.45	.41				
20. Spoke(E)	.39	.00	-.03	-.01	-.09	-.34	-.08	-.15	.27	.02	-.17	.26	.13	.06	-.04	.02	-.17	-.32	.33			
21. Spoke(D)	.44	.00	-.03	-.01	-.09	-.33	-.10	-.20	.23	.01	-.14	.28	.14	.08	-.04	.02	-.14	-.35	.27	1.0**		
22. Code Test	-.72*	.00	.26	-.27	-.16	.31	.51	.13	-.09	-.41	-.47	-.16	.22	-.55	-.23	.30	.03	.77*	.38	-.46	-.50	

*p .05
**p .01

TABLE 5. Intercorrelation of At-Sea One Scores of 22 Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. MSS																						
2. Emesis	.92**																					
3. Urine Prod	.44	.49																				
4. Urine SpG.	-.57	-.46	-.85**																			
5. Δ % 17-OHCS	-.60	-.43	-.75*	.91**																		
6. Δ % CATs	-.05	-.22	-.54	.42	.02																	
7. % NAVPLOT	.28	.20	.59	-.43	-.36	-.35																
8. Fatigue	.18	-.11	-.51	.01	-.07	.45	-.26															
9. Concentration	-.27	-.24	-.47	.70	.65	.20	.03	-.11														
10. Skepticism	.46	.56	-.28	.28	.12	.41	-.29	.13	-.07													
11. Anxiety	.79*	.59	.64	-.89**	-.92**	-.08	.29	.28	-.53	-.04												
12. Tracking	-.78*	-.53	-.19	.48	.60	-.26	-.31	-.60	.15	-.21	-.79*											
13. Gram Reasoning	-.33	-.32	-.29	.08	.15	.00	-.25	.47	-.32	-.06	-.12	-.03										
14. Complex Low Error	-.02	-.15	.71*	-.76*	-.71*	-.32	.42	-.14	-.44	-.76*	.54	-.13	.02									
15. Complex Med Error	-.16	-.26	.64	-.68	-.53	-.49	.38	-.18	-.38	-.87**	.39	.06	.04	.96**								
16. LS(1)	-.28	-.19	-.38	.45	.46	.09	-.04	-.12	-.10	.44	-.59	.46	.04	-.52	-.43							
17. LS(2)	-.52	-.40	-.43	.49	.57	-.03	-.47	-.25	.04	.10	-.66	.79*	-.18	-.39	-.21	.69						
18. LS(4)	-.75*	-.56	-.31	.58	.57	.05	-.50	-.50	.43	-.24	-.71*	.85**	.17	-.14	-.02	.09	.62					
19. Spoke(C)	.64	.52	.78*	-.83*	-.76*	-.39	.45	-.11	-.21	-.35	.84**	-.51	-.45	-.64	.57	-.70	-.54	-.40				
20. Spoke(E)	.15	.08	.05	-.33	-.04	-.52	-.21	.33	-.08	-.41	.33	-.16	.18	.22	.35	-.52	-.11	-.11	.43			
21. Spoke(D)	.57	.52	.06	-.40	-.38	.03	-.54	.39	-.47	.34	.58	-.38	-.01	-.05	-.10	-.31	-.05	-.27	.35	.53		
22. Code Test	-.89**	-.79*	-.43	.61	.64	.02	-.29	-.33	.27	-.29	-.84**	.90**	-.01	-.14	.04	.53	.82*	.80*	-.62	-.22	-.50	

*p < .05
**p < .01

TABLE 6. Intercorrelation of At-Sea Two Scores of 22 Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. MSS																						
2. Emesis	.97**																					
3. Urine Prod	-.10	.03																				
4. Urine SpG.	-.11	-.27	-.83*																			
5. Δ % 17-OHCS	-.40	-.52	-.37	.82*																		
6. Δ % CATs	-.19	-.19	.55	.00	.50																	
7. % NAVPLOT	.36	.26	-.58	.75*	.61	.13																
8. Fatigue	.38	.48	.00	-.02	-.03	.12	.54															
9. Concentration	-.35	-.10	.50	-.45	-.19	.14	-.25	.30														
10. Skepticism	.62	.62	.41	-.27	-.16	.47	.02	.07	-.26													
11. Anxiety	.47	.59	.22	-.11	-.04	.34	.28	.54	.17	.69												
12. Tracking	-.69	-.62	-.08	.16	.32	-.10	-.03	-.15	.57	-.69	-.23											
13. Gram Reasoning	.53	.55	-.01	.07	.03	.15	.62	.79*	-.11	.17	.32	-.28										
14. Complex Low Error	-.34	-.33	-.23	.37	.38	.12	.07	-.01	-.47	-.13	-.02	-.02	.12									
15. Complex Med Error	-.22	-.33	-.19	.28	.29	.03	-.13	-.64	-.76*	.01	-.39	-.11	-.18	.65								
16. LS(1)	.55	.56	.00	-.09	-.14	-.11	.27	.00	-.02	.37	.41	.10	.24	-.41	-.06							
17. LS(2)	-.54	-.52	.47	-.01	-.48	-.73*	-.09	.21	.42	-.19	-.11	.36	.25	.15	-.05	-.29						
18. LS(4)	-.38	-.38	.04	-.08	-.06	-.18	-.22	.06	.53	-.44	-.36	.17	-.38	-.40	-.56	-.62	.16					
19. Spoke(C)	.76*	.78*	.07	.03	-.01	.32	.61	.77*	-.06	.63	.75*	-.54	.76*	-.14	-.42	.34	-.02	-.29				
20. Spoke(E)	-.03	.10	.40	-.29	-.03	.20	.11	.37	.40	-.09	.21	.42	.57	.04	-.11	.44	-.52	-.43	.20			
21. Spoke(D)	-.30	-.17	.03	-.14	-.11	-.25	-.01	.39	.39	-.64	-. 9	.54	.41	.26	-.12	-.05	.38	-.04	-.14	.73*		
22. Code Test	.46	.36	-.13	.07	-.03	-.10	.49	.32	.05	-.10	-. 0	-.07	.53	-.60	-.35	.36	.11	.11	.36	.23	.11	

*p < .05
**p < .01

While the limitations inherent in our small sample size generally reduce the statistical power in the elucidation of the interrelationships of our 22 variables, some logical patterns have been revealed in the correlation matrices.

First, on the control day, there were 16 significant correlations, while at sea on Day 1, 31 relationships were significant. During the second day at sea, only 12 relationships were significant and 8 of these 12 were different from those obtained on the first day. These relationships are presented in Table 7.

These general results are consistent with the overall findings reported earlier for the performance tests; that is, a marked effect occurring on the first exposure to motion, followed by a lessening of that effect on the second day.

In interpreting the relationship between the physiology, mood and performance relationships presented in the correlation tables, one must remember the unit of measure for the particular task involved, i.e. Spoke tasks are all time based, as are Letter Search tasks. Complex Counting is an error-based score. Therefore for such tasks, an increase in the score indicates a <u>decrement</u> in performance. The Code Substitution, CTT, Navigation Plotting and Grammatical Reasoning tasks all have measures which indicate improvement in performance as the score increases, i.e. % correct, number attempted, etc.

Navigation and Plotting accuracy was significantly reduced upon exposure to vessel motion ($p < .01$). Hour effects were also significant in nature ($p < .025$) as can be seen in Figure 4. Analysis by t-test analyses for various steaming leg combinations revealed that greater accuracy was obtained during those legs which possessed a following sea component ($p < .05$) such as stern and quartering seas.

TABLE 7. Significant Correlations Across Testing Days

	Control	At-Sea 1	At-Sea 2
MSSS and			
Critical Tracking Task (λ_c)		-.78	
Four-Letter Search attempts		-.75	
Code Substitution attempts	-.72	-.89	
Spoke Control times			.76
Emesis incidence		.92	.97
ANXIETY		.79	
Fatigue	.78		
EMESIS and			
MSSS		.92	.97
Spoke Control times			.78
URINE PRODUCTION and			
Complex Counting errors (Low tone)	-.78	.71	
Spoke Control times		.78	
Specific gravities (urine)	-.99	-.85	-.82
17-OHCS excretion rates	-.95	-.75	
Catecholamines excretion rates	.86		
URINE SPECIFIC GRAVITY and			
Complex Counting errors (Low tone)		-.76	
Spoke Control times		-.83	
Nav/Plot errors			.75
17-OHCS excretion rate	.92	.91	.83
Catecholamines excretion rate	-.83		
Anxiety score		.89	
17-HYDROXYCORTICOSTERIODS (17-OHCS) and			
Complex Counting errors (Low)		-.71	
Spoke Control times		-.76	
Catecholamines	-.73		
Anxiety		-.92	
CATECHOLAMINE			
Two-Letter Search attempts			.73
Complex Counting errors (Low)	-.78		
Complex Counting errors (Med)	-.71		
SKEPTICISM and			
Complex Counting errors (Low)		-.76	
Complex Counting errors (Med)		-.86	
Grammatical Reasoning # correct	-.88		
ANXIETY and			
Critical Tracking Task (λ_c)		-.79	
Four-Letter Search attempts		-.71	
Spoke Control times		.84	
Code Substitution attempts		-.83	
FATIGUE and			
Grammatical Reasoning # correct			.79
Spoke Control times			.77
Concentration	.73		
CONCENTRATION and			
Complex Counting errors (Med)			-.76
Two-Letter Search	-.90		
CRITICAL TRACKING TASK (λ_c) and			
Two-Letter Search attempts		.79	
Four-Letter Search attempts		.85	
Code Substitution attempts		.90	
CODE SUBSTITUTION ATTEMPTS and			
Two-Letter Search attempts		.82	
Four-Letter Search attempts	.77	.81	
COMPLEX COUNTING ERRORS			
Low tone and Med tone	.88	.96	
GRAMMATICAL REASONING and			
Spoke Control times			.76
SPOKE TEST TIMES			
Experimental and Difference	.99		.73
TOTAL # OF SIGNIFICANT CORRELATIONS	17	28	13

NOTE: Correlations which exceed .707 are significant at $p < .05$, two-tailed test conditions which exceed .834 are significant at $p < .01$, two-tailed test ($N = 8$ ∴ $N-2 = 6$ df) see Edwards, 1976, p. 20. Table V.

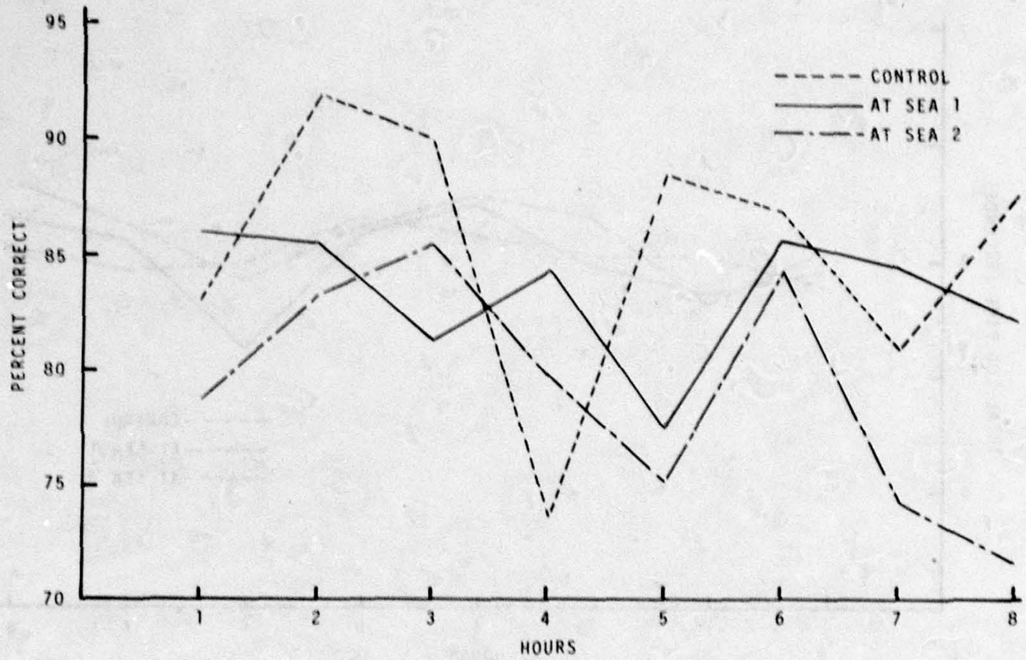

Figure 4. Navigation Plotting performance dockside and at sea

The Spoke Test has three measures of performance: a control phase, which essentially provides a measure of motor performance unimpeded by a stimulus search requirement; a search and tap phase, which includes this search requirement; and a difference score, which is thought to extract the motor component from the integrated search and tap act.

As can be seen in Table 2 and Figures 5, 6, and 7, results obtained from ANOVAs performed on "control", "experimental" and "difference" (Control - Experimental) times obtained with the Spoke Test indicated no significant changes associated with the introduction of vessel motion; however, hour effects were significant for "control" times ($p < .001$), "experimental" times ($p < .01$) and "difference" times ($p < .05$).

Student t-tests performed on hourly means showed no significant differences between various combinations of steaming legs. Significant rela-

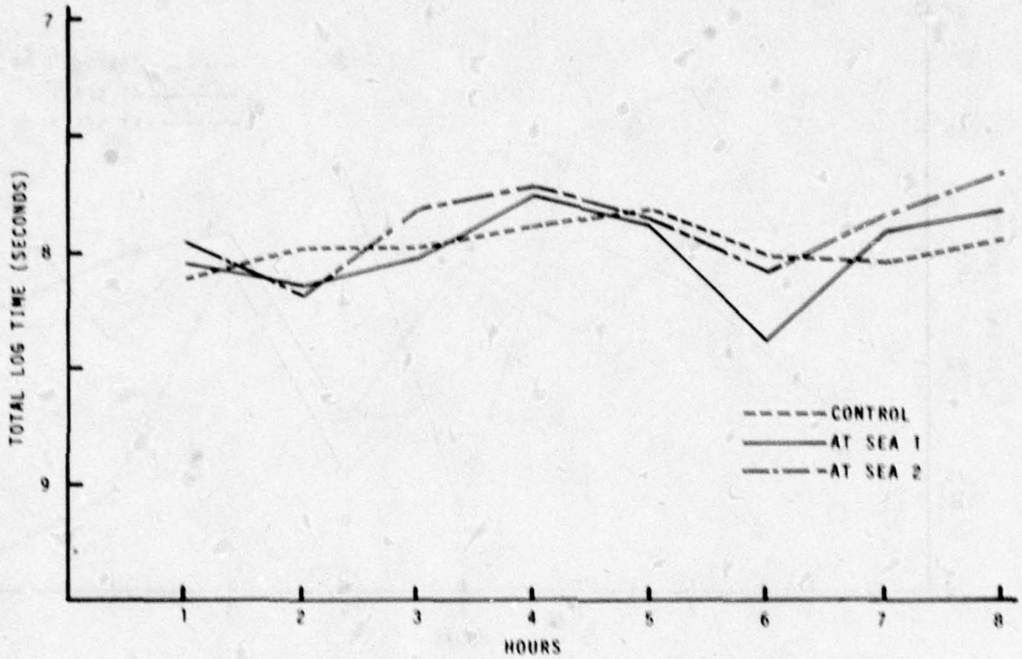

Figure 5. Spoke Test (Control) performance dockside and at sea

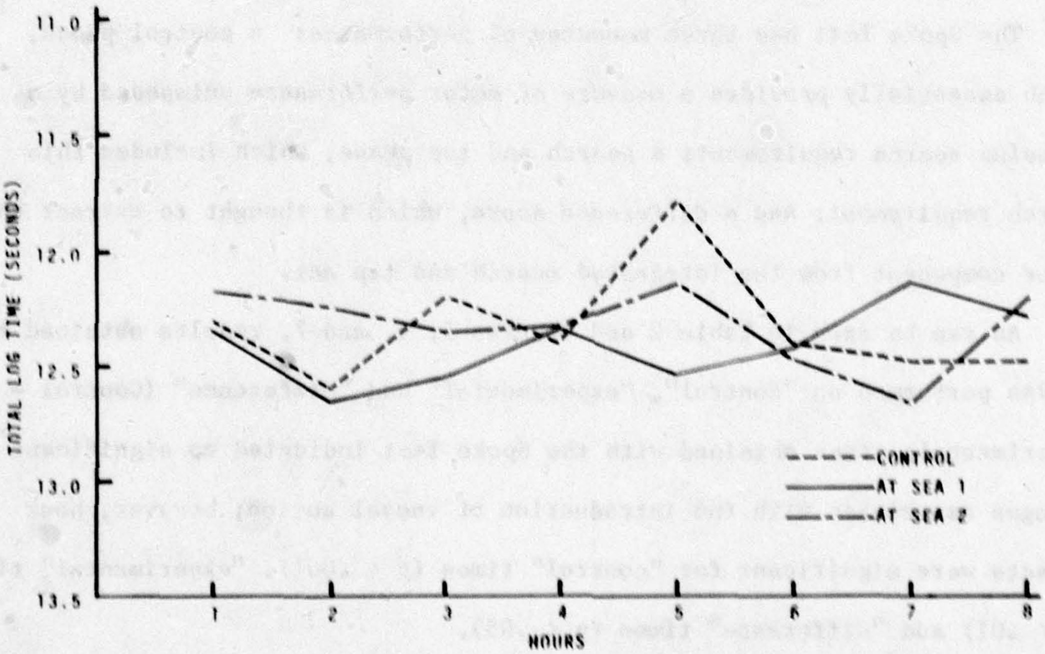

Figure 6. Spoke Test (Experimental) performance dockside and at sea

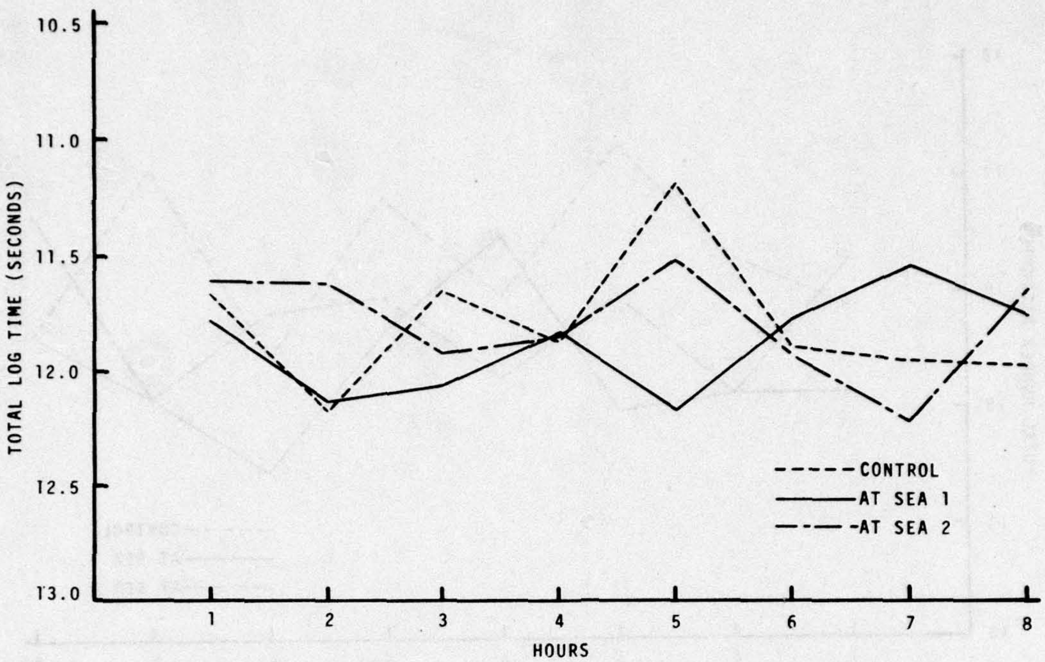

Figure 7. Spoke Test performance difference scores dockside and at sea

tionships were found between Spoke Experimental and Spoke Difference scores on the control day, ($r = .99$, $p < .001$) and during the first sea day between Spoke Control and urine production ($r = .78$, $p < .05$), specific gravity ($r = -.83$, $p < .01$), 17-OHCS ($r = -.76$, $p < .05$) and anxiety ($r = .84$, $p < .001$). A significant correlation was obtained between Navigation Plotting and urine specific gravity on Day 2 ($r = .75$, $p < .05$).

Grammatical Reasoning performance was negatively correlated with skepticism on the control day ($r = -.88$, $p < .01$) and positively correlated with fatigue on the second at-sea day. Figure 8 shows the performance on this task across hours and days.

The Letter Search ANOVA revealed a significant ($p < .01$) decrement in performance over days for the Single Letter Search task, no change for the Two-Letter Search task, and a significant improvement for the Four-Letter

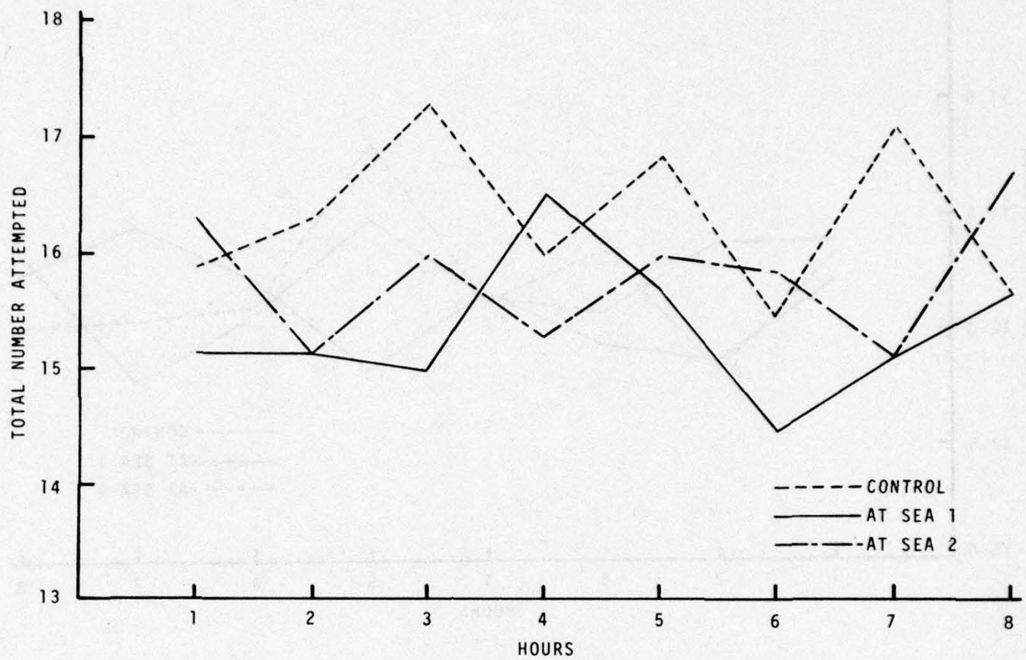

Figure 8. Grammatical Reasoning performance dockside and at sea

Search task (see Table 3 for the mean day-by-day changes). These data can be seen graphically in Figures 9 through 11. In Figure 12 the data have been collapsed across hours to better illustrate the per item scan time performance changes. Single-Letter Search performance degraded significantly on Day 1, but by Day 2 performance had significantly improved to near control levels. The performance in Two-Letter Search is similar but the values fail to reach significance. The performance on the Four-Letter Search task significantly improved across testing days.

Performance in the Complex Counting task, as shown in Figures 13 and 14, resulted in no significant differences between dockside and steaming days for low (100 Hz) or medium (900 Hz) tones. Although there were no significant hour of steaming leg effects observed with the medium tone, low tone counting

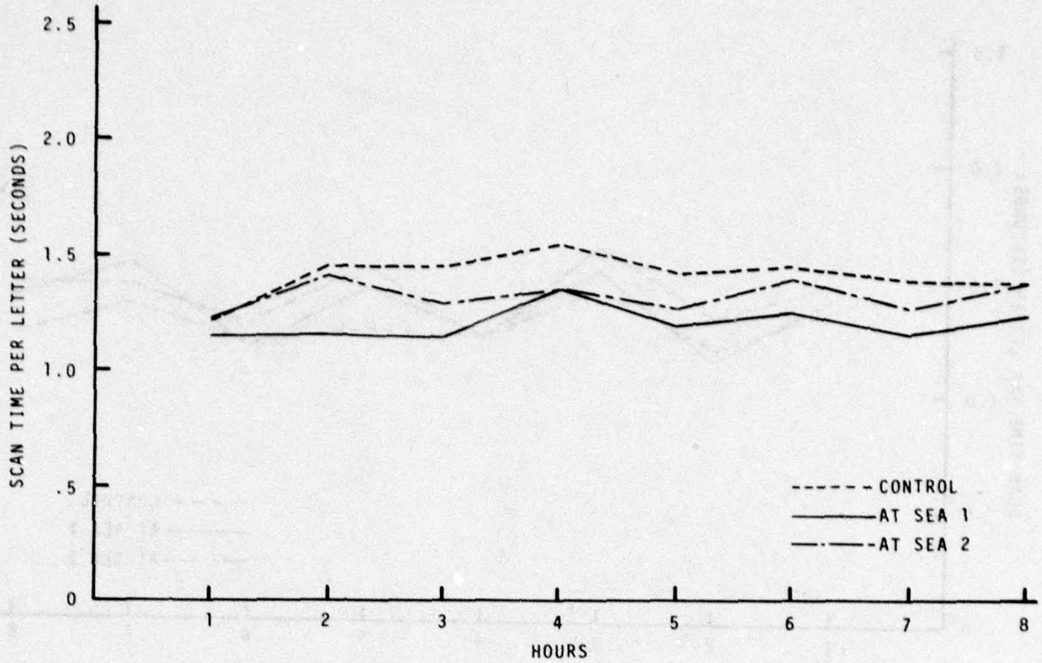

Figure 9. Single-Letter Search performance dockside and at sea

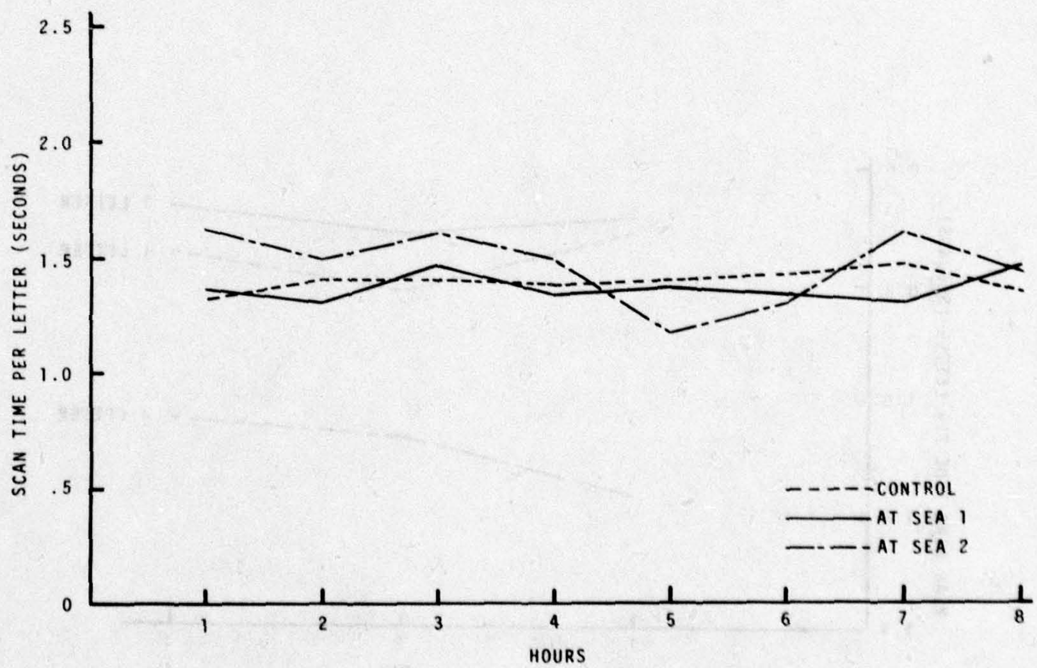

Figure 10. Two-Letter Search performance dockside and at sea

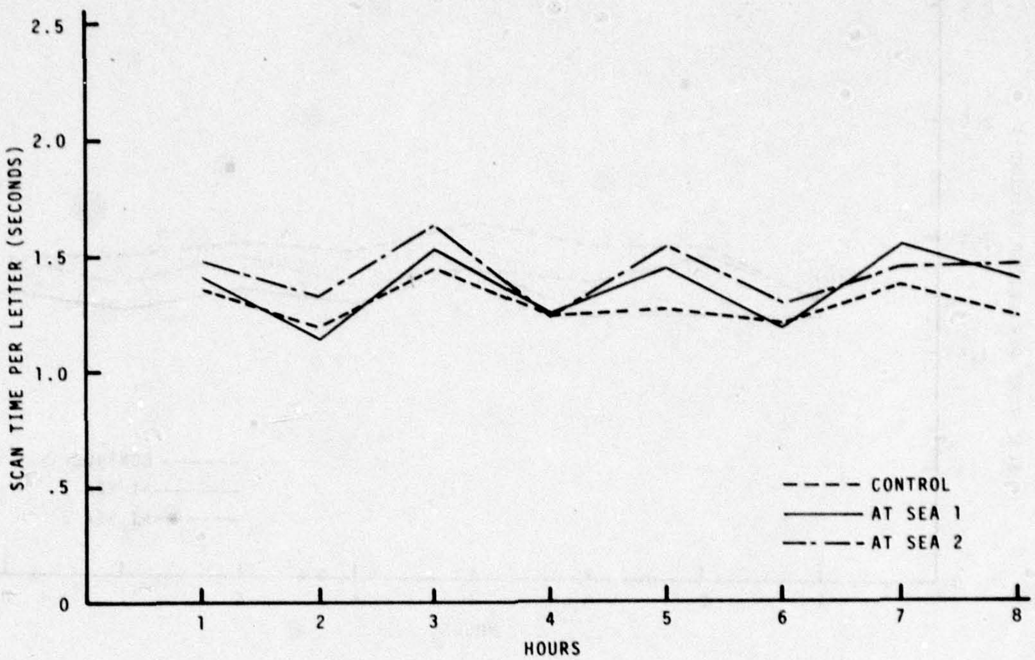

Figure 11. Four-Letter Search performance dockside and at sea

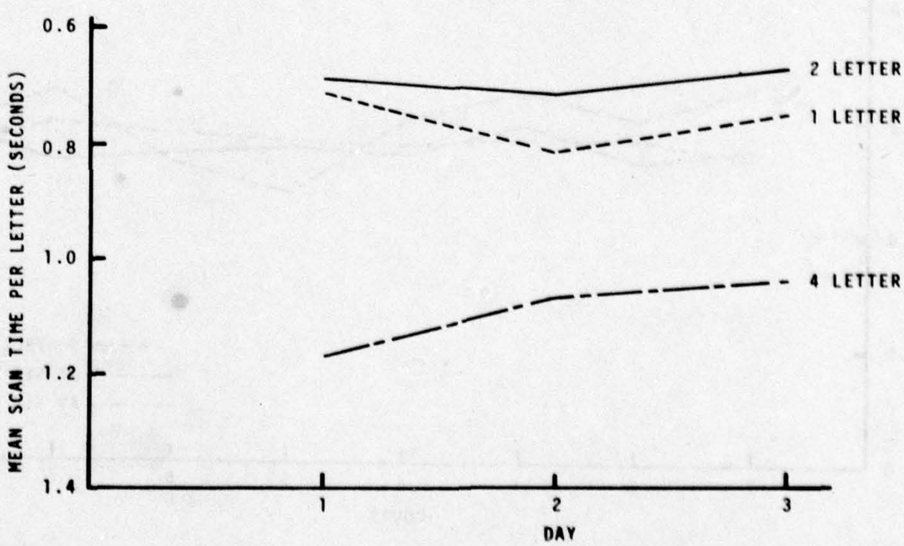

Figure 12. Letter Search performance dockside and at sea

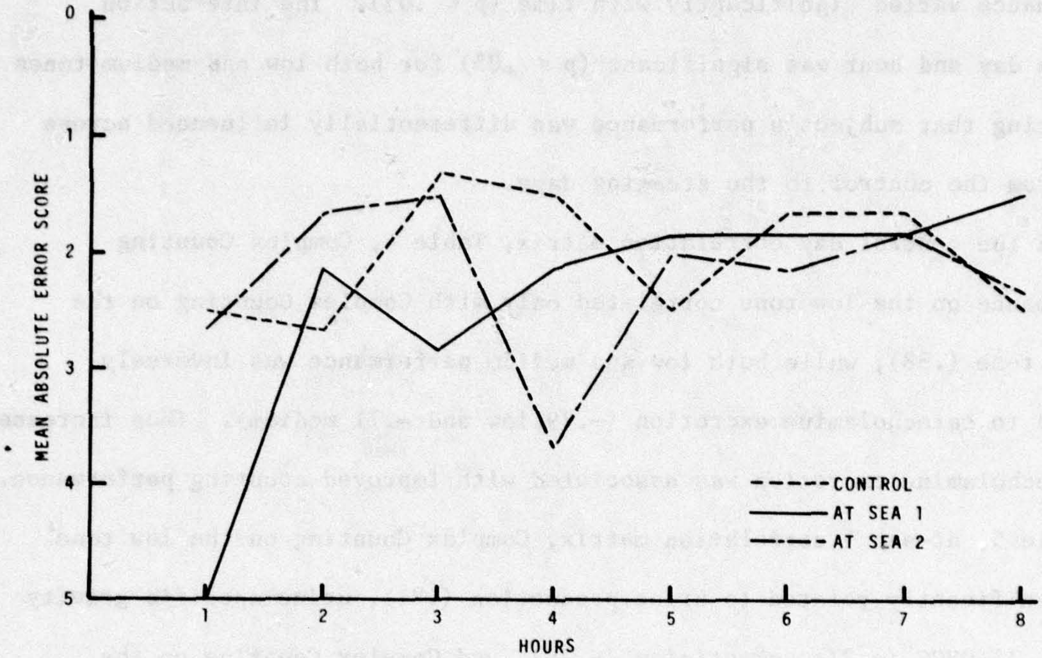

Figure 13. Complex Counting (medium tone) performance dockside and at sea

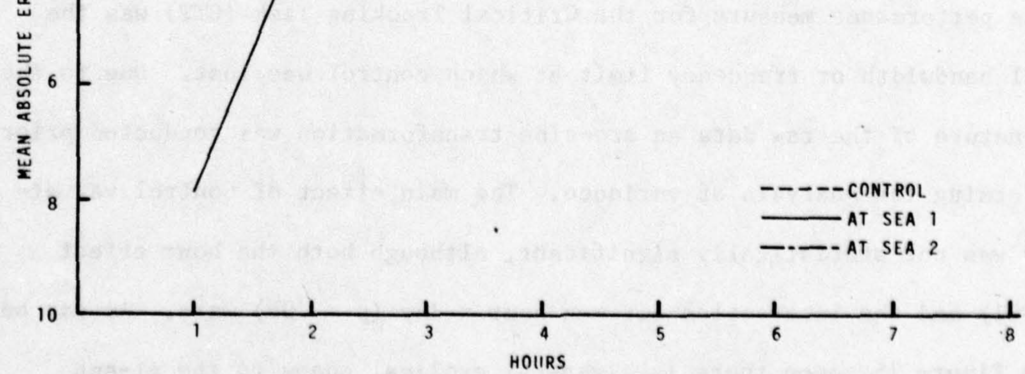

Figure 14. Complex Counting (low tone) performance dockside and at sea

performance varied significantly with time ($p < .05$). The interaction between day and hour was significant ($p < .05$) for both low and medium tones indicating that subject's performance was differentially influenced across time from the control to the steaming days.

In the control day correlation matrix, Table 4, Complex Counting performance on the low tone correlated only with Complex Counting on the medium tone (.88), while both low and medium performance was inversely related to catecholamine excretion (-.79 low and -.71 medium). Thus increase in catecholamine excretion was associated with improved counting performance. In Table 5, at-sea 1 correlation matrix, Complex Counting on the low tone was significantly related to urine production (.71), urine specific gravity (-.76), 17-OHCS (-.71), skepticism (-.76), and Complex Counting on the medium tone (.96). Medium tone performance on this task was related to skepticism (-.86) on the first sea day, and to catecholamine excretion rates (-.71) on the control day. During the second day at sea, only subject concentration and Complex Counting on the medium tone (-.76) were significantly correlated. The Complex Counting task employs an error-based measure; thus, inverse relationships indicate that performance improved with increases in the related variable.

The performance measure for the Critical Tracking Task (CTT) was the critical bandwidth or frequency limit at which control was lost. Due to the skewed nature of the raw data an arc-sine transformation was conducted prior to performing the analysis of variance. The main effect of Control vs. at-sea day was not statistically significant, although both the hour effect ($p < .001$) and the interaction between hour x day ($p < .05$) were. As can be seen in Figure 15, seen there is a general cyclical shape to the at-sea performance curves, compared to the control day. All three days exhibit the

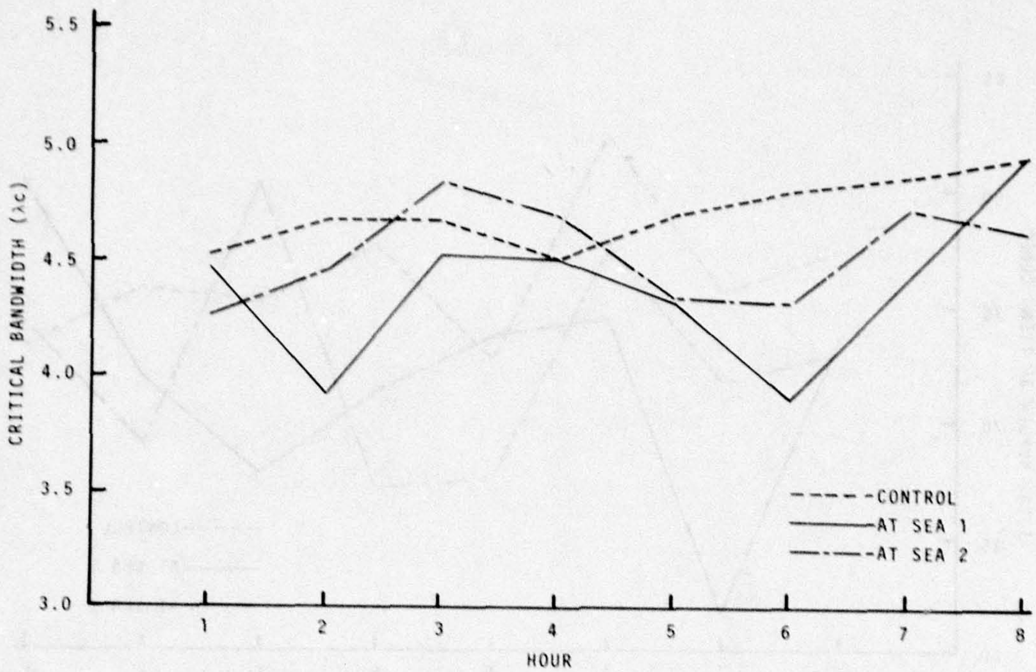

Figure 15. Critical Tracking Task (CTT) performance dockside and at sea

characteristic "end spurt" improvement during the final testing periods. In Table 7, CTT performance during the first at-sea day is highly correlated with Two-Letter Search (.79), Four-Letter Search (.85) and Code Substitution (.90). During the second at-sea day, these same relationships failed to reach statistical significance.

In the Code Substitution task, the measure of performance was the total number of items coded in a two-minute period. Table 2 shows that the main effects of Days and Hours were not statistically significant. The interaction effect, however, was significant at the $p < .05$ level, indicating that performance during the day was not the same from day 1 to day 3. Figure 16 portrays these results graphically. During the control day (Table 7), Code Substitution performance was correlated with Four-Letter Search (.77), and

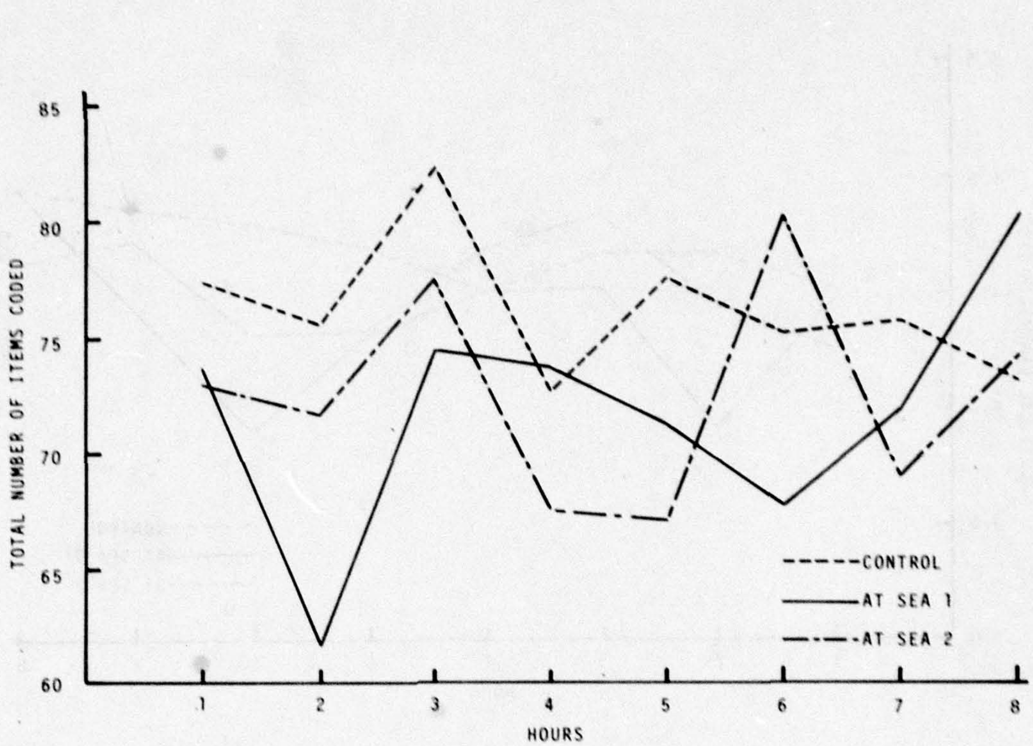

Figure 16. Code Substitution performance dockside and at sea

motion sickness symptomatology (-.72). During the first at-sea day, both Two and Four-Letter Search performance were related to Code Substitution performance (.82 and .81 respectively). Additionally, anxiety scores were negatively related to Code Substitution performance (-.83).

MOOD CHANGES

Table 8 summarizes the results of ANOVA conducted on the Mood Checklist data. Fatigue scores increased significantly at sea ($p < .01$). Subjective reports of concentration and skepticism changed significantly with respect to the time of day ($p < .05$); however, the dimension of fatigue failed to show these systematic changes. Anxiety reports changed across hours during the testing days. These mood dimensions were then examined on a day-by-day basis

using Dunnett's t-test procedures. Table 9 presents the results of these comparisons.

TABLE 8. Summary of Significance Levels from Analysis of Variance of Mood Adjective Checklist Scores

	DAY	HOUR	D X H
Concentration	N.S.	$p < .05$	N.S.
Skepticism	N.S.	$p < .05$	N.S.
Fatigue	$p < .01$	N.S.	$p < .05$
Anxiety	N.S.	N.S.	$p < .01$
Aggression	N.S.	N.S.	N.S.
Vigor	N.S.	N.S.	N.S.
Elation	N.S.	N.S.	N.S.
Egotism	N.S.	N.S.	N.S.
Sadness	N.S.	N.S.	N.S.
Surgency	N.S.	N.S.	N.S.

TABLE 9. Comparison of Mood Dimensions: Control vs At-Sea

	Control vs. Sea 1	Control vs. Sea 2	Sea 1 vs. Sea 2
1. Fatigue	Sign. Increase	Sign. Increase	N.S. Decrease
2. Skepticism	N.S. Increase	N.S. Decrease	N.S. Decrease
3. Concentration	N.S. Increase	N.S. Decrease	N.S. Decrease
4. Anxiety	N.S. Increase	N.S. Increase	N.S. Decrease

NOTE: A two-tailed test with a critical value of $p < .05$ was employed in all comparisons (see Winer, 1971, p. 201 for details).

It can be seen that fatigue increased significantly across both at-sea days; however, comparisons of both steaming days show that fatigue lessened on the second day. Subject skepticism and concentration scores both increased,

then decreased in a similar but not statistically significant manner. Anxiety scores increased during the at-sea days, but the values did not reach statistical significance.

Figures 17 through 20 present the changes which occurred across the hours of the testing days for the mood dimensions of fatigue, skepticism, concentration and anxiety, respectively.

On the control day in Table 7, the mood dimensions of fatigue, concentration, and skepticism showed significant correlations. Fatigue was correlated with motion sickness symptomatology (.78) and concentration (.73); concentration with Two-Letter Search (-.90), and skepticism with Grammatical Reasoning (-.88). On the first day at sea, subject anxiety was correlated with the physiology variables of motion sickness symptomatology (.78), urine specific gravity (.89) and 17-OHCS (-.92). Also anxiety was correlated with the following performance measures: CTT (-.79), Four-Letter Search (-.71), Spoke Control (.84) and Code Substitution (-.83). This finding indicates that as anxiety scores increased, performance on all of these measures would be predicted to decrease.

On the second sea day (Table 7) the following mood relationships were observed: fatigue with Grammatical Reasoning (.79), fatigue with Spoke Control (.77), anxiety with Spoke Control (.75) and concentration with the medium tone Complex Counting task (-.76).

MOTION SICKNESS

Motion sickness symptomatology severity scores were generated from the symptoms reported by subjects on motion sickness symptomatology questionnaires administered each testing cycle. As would be expected, MSSS scores

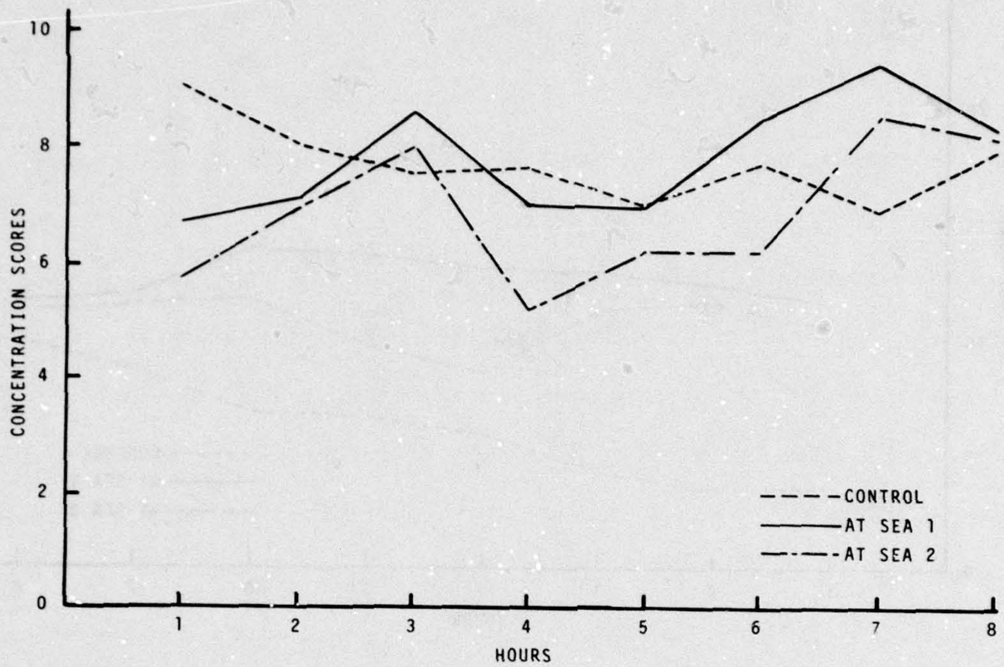

Figure 17. Subject report of concentration dockside and at sea

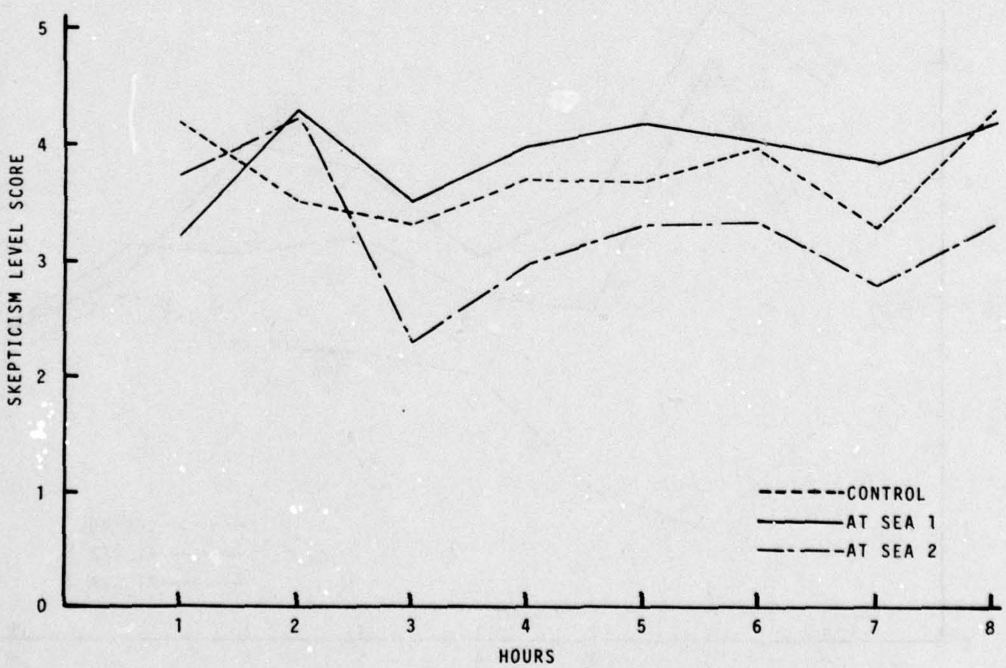

Figure 18. Subject report of skepticism dockside and at sea

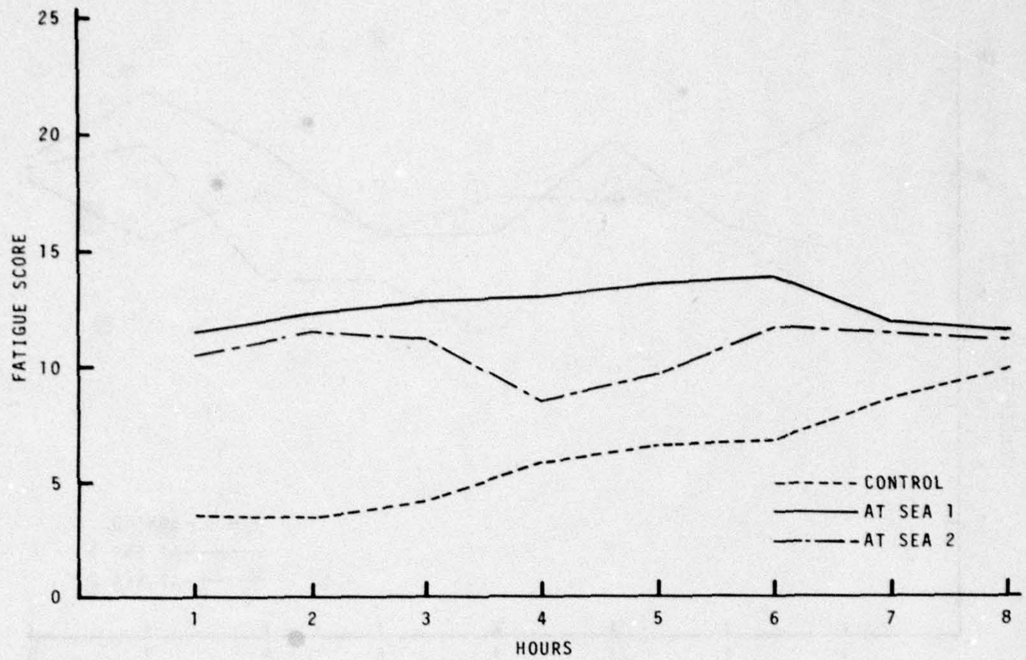

Figure 19. Subject report of fatigue dockside and at sea

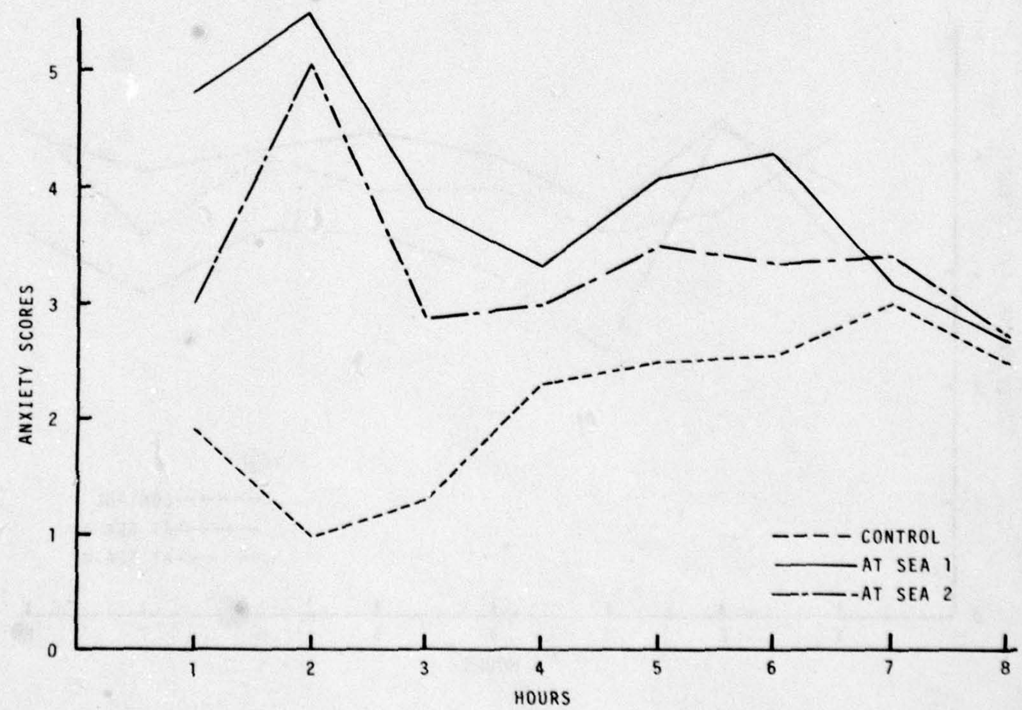

Figure 20. Subject report of anxiety dockside and at sea

Table 10. Summary of Results Obtained From ANOVAs Performed on Physiological Indices

PHYSIOLOGICAL INDICE	METRIC	INFLUENCE OF VESSEL MOTION	MAIN EFFECTS DAY	MAIN EFFECTS HOUR	INTERACTIONS DAY x HOUR
Motion Sickness Symptomatology	Collective Score	Increased number and severity of symptoms	$p < .001$	$p < .001$	$p < .01$
Emesis	% of S. Population	Increase	$p < .001$	$p < .01$	$p < .01$
Urine Production (Volume)	ml/2 Hr	Reduced	$p < .05$	N.S.	$p < .001$
Urine Specific Gravity	-	Increased	$p < .05$	N.S.	N.S.
Urinary Excretion 17-OHCS	mg/2 Hr	Excretion increased	$p < .05$	N.S.	N.S.
Urinary Excretion Catecholamines			$p < .05$	N.S.	$p < .001$

NOTE: Significant F ratios were converted to probability values and entered under the main effects of interactions column. Those values which did not reach the $p < .05$ level of significance are indicated by N.S.

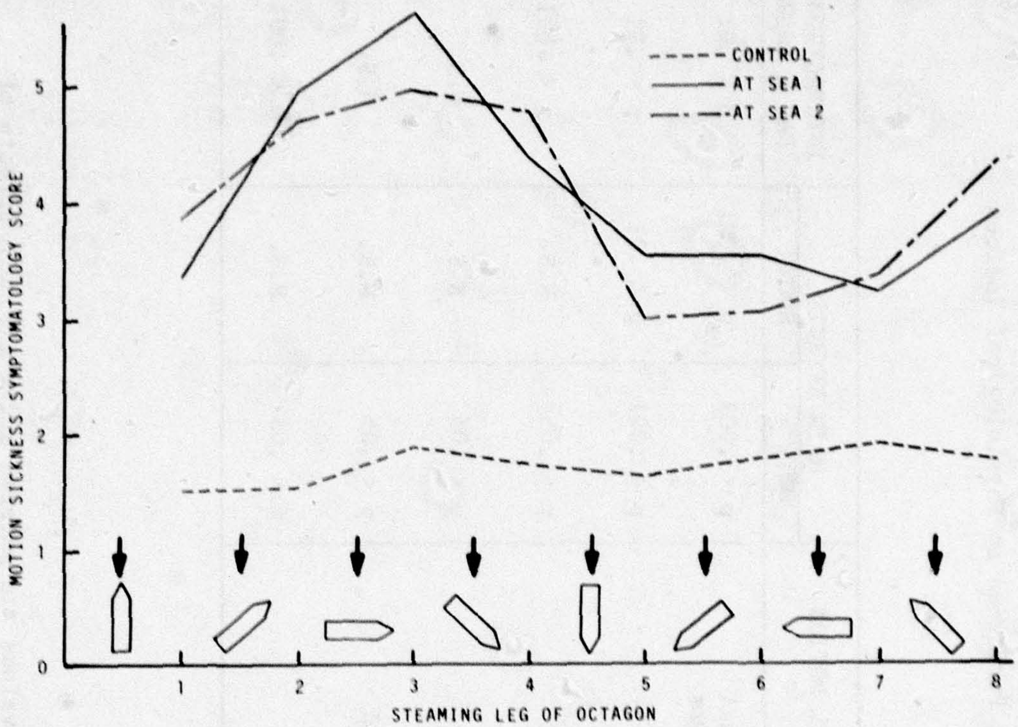

Figure 21. Motion sickness symptomatology per octagonal steaming leg

were much higher at sea than during dockside data collection ($p < .001$). There were significant periodic variations in the number and severity of symptoms associated with vessel course changes ($p < .001$) as can be seen in Figure 21.

Although the second steaming day's symptomatology levels were slightly lower than the first day at sea, their correlation between the mean at-sea Day 1 and Day 2 scores remained significant ($r = .70$, $p < .01$). Student t-tests revealed motion sickness severity to be much greater on steaming legs which forced the boat to steam into the primary swell (i.e., head or bow seas were encountered) than when the vessel steamed with the seas. The mean difference obtained between symptomatology scores associated with steaming

into the primary swell vs. steaming with the swell was 1.83 ± 2.25 on the MSSS a scale of 0-7 ($p < .05$).

The incidence of observed emesis is plotted as episode frequency versus steaming leg, shown in Figure 22. A t-test conducted on the percentage of subjects experiencing emesis during legs with head sea components versus steaming legs with following seas showed steaming legs with head seas were more provocative (11 ± 13.5%, $p < .05$). This finding is consistent with the MSSS results reported previously.

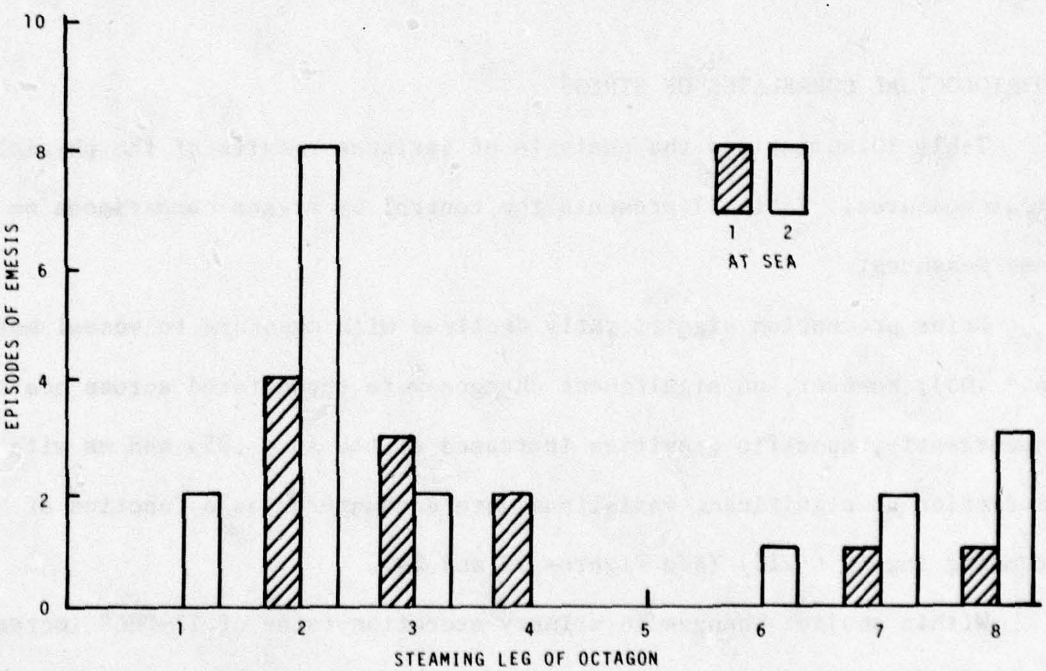

Figure 22. Episodes of emesis per octagonal steaming leg

As can be seen in the correlation matrix for the control day (Tables 4 and 7), MSSS was correlated with fatigue (.78), fatigue correlated with concentration (.73), concentration with Two-Letter Search (-.90) and skepticism with Grammatical Reasoning (-.88).

On the first day at sea, anxiety was correlated with motion sickness symptomatology (.78), CTT (-.78), Four-Letter Search (-.78) and Code Substitution (-.89). Skepticism was correlated with both forms of the Complex Counting task (-.76 low, -.86 medium), while anxiety was correlated negatively with CTT (-.79), Four-Letter Search (-.71), Spoke Control (-.84) and Code Substitution (-.83).

Fatigue was correlated with Grammatical Reasoning (.79) and Spoke Control (.77); concentration with Complex Counting on medium tone (-.76), and anxiety was correlated with Spoke Control scores (.75).

PHYSIOLOGICAL CORRELATES OF STRESS

Table 10 summarizes the analysis of variance results of the physiological measures. Table 11 presents the control by at-sea comparisons on these same measures.

Urine production significantly declined with exposure to vessel motion ($p < .05$); however, no significant changes were encountered across hours. Concurrently, specific gravities increased at sea ($p < .05$) and as with urine production no significant variations were encountered as a function of steaming leg ($p < .10$) (see Figures 23 and 24).

Within subject changes in urinary excretion rates of 17-OHCS increased significantly from control values with exposure to the steaming environment ($p < .05$); however, no significant hour, or steaming leg, effects were found (see Figure 25).

The average increase ranged from 123 ±99% on steaming day 1 to 232 ± 157% for steaming day 2.

Within subject changes in urinary excretion rates of catecholamines increased significantly from control values with exposure to the steaming

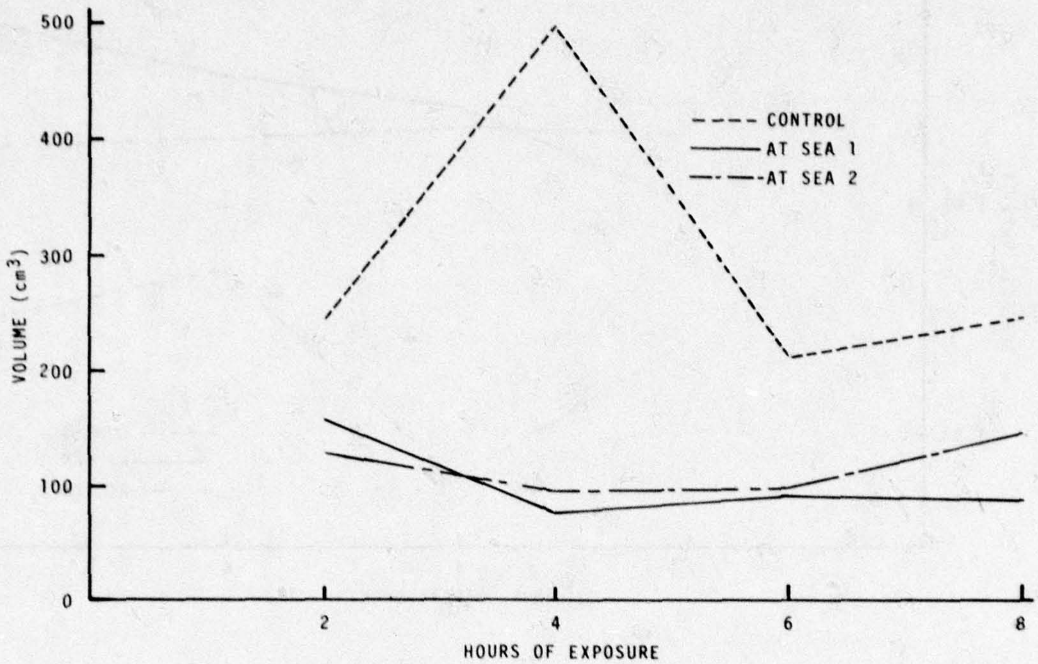

Figure 23. Urine production dockside and at sea

TABLE 11. Comparison of Physiological Indices: Control versus At-Sea

	Control vs. Sea 1	Control vs. Sea 2	Sea 1 vs. Sea 2
1. Motion Sickness Symptomatology	Sign. Increase	Sign. Decrease	N.S. Decrease
2. Emesis	-	-	
3. Urine Production (Volume)	Sign. Decrease	Sign. Decrease	N.S. Decrease
4. Urine Specific Gravity	N.S. Increase	N.S. Increase	No Change
5. Urine Excretion 17-OHCS	N.S. Increase	Sign. Increase	Sign. Increase
6. Urine Excretion Catecholamines	N.S. Increase	Sign. Increase	Sign. Decrease

NOTE: Dunnett's *t*-test was conducted to examine changes between control and treatment groups. A two-tailed test with $p < .05$ as a criterion was employed to determine the significance of the differences obtained (see Winer, 1971, p. 202 for rationale and details of this procedure).

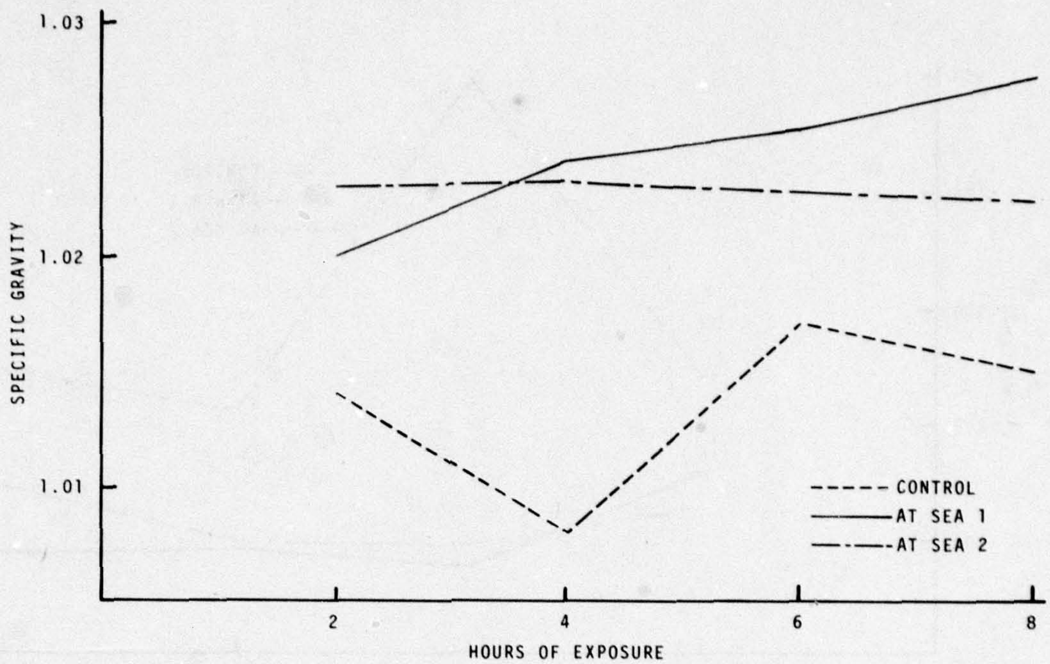

Figure 24. Urine specific gravity dockside and at sea

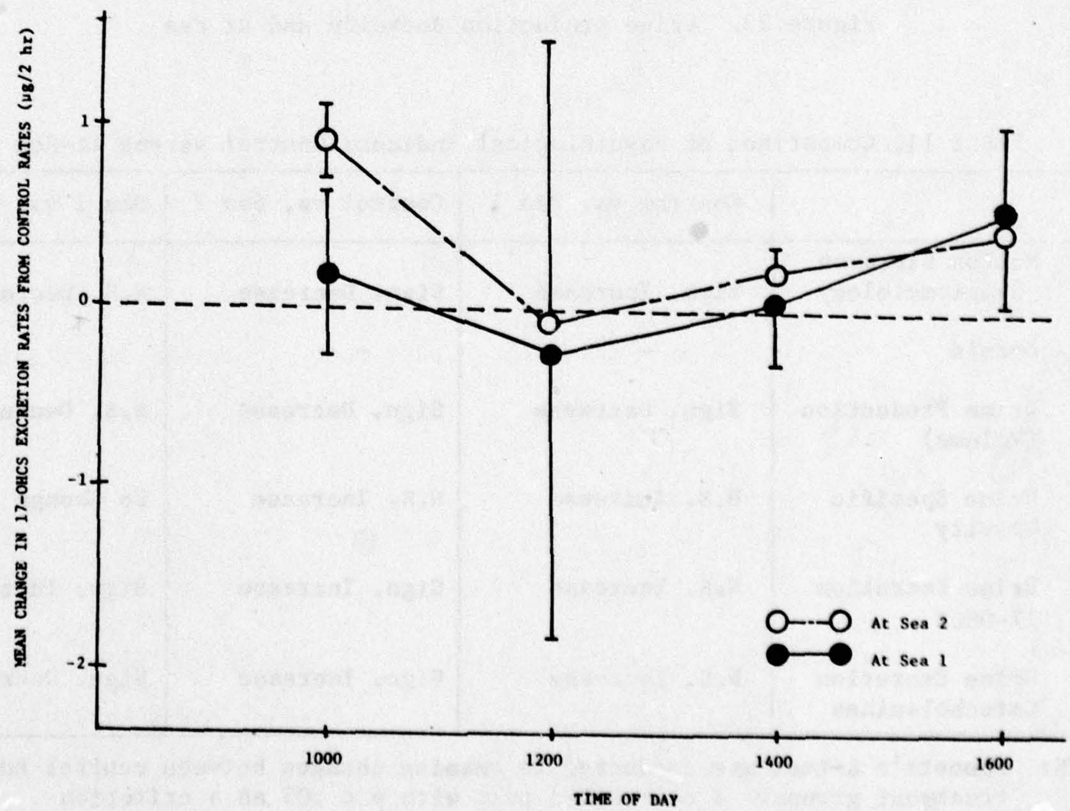

Figure 25. Changes in 17-OHCS excretion rates from dockside to at sea

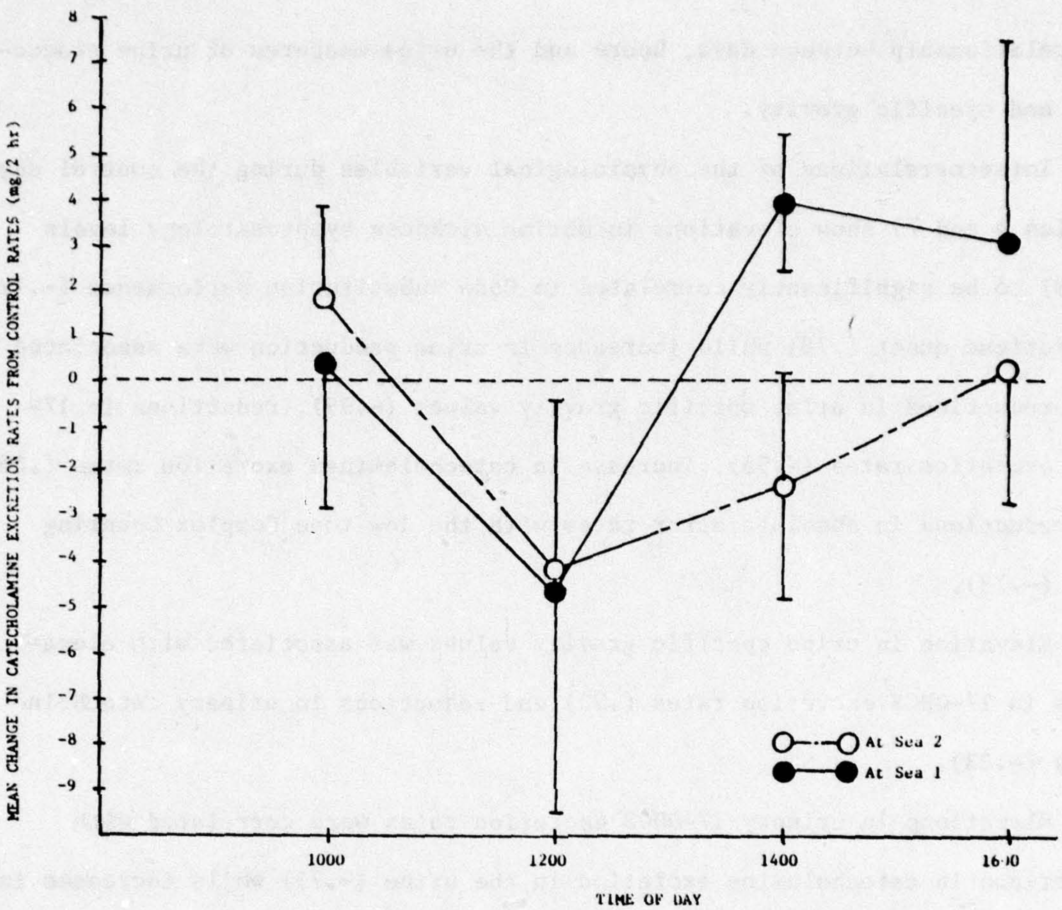

Figure 26. Changes in urinary catecholamine excretion rates from dockside to at sea

environment as well ($p < .05$). As with 17-OHCS excretion rates, no significant variations were found in catecholamine excretion rates within either day of steaming (see Figure 26).

The average increase in catecholamine excretion rates ranged from 508 ±958% on steaming day 1 to 197 ±425% for steaming day 2.

Table 11 presents a summary of comparisons made between control and at-sea conditions on the physiological indices. The results are consistent with the ANOVA, but additionally indicate at what point in the vessel motion exposure changes were most apparent. Figures 23 and 24 describe graphically

the relationship between days, hours and the urine measures of urine production and specific gravity.

Intercorrelations of the physiological variables during the control day (Tables 4 and 7) show elevations in motion sickness symptomatology levels (MSSS) to be significantly correlated to Code Substitution performance (-.72) and fatigue onset (.78) while increases in urine production were associated with reductions in urine specific gravity values (-.99), reductions in 17-OHCS excretion rates (-.95), increase in catecholamines excretion rates (.86) and reductions in absolute error rates with the low tone Complex Counting task (-.78).

Elevation in urine specific gravity values was associated with elevations in 17-OHCS excretion rates (.92) and reductions in urinary catecholamines (-.83).

Elevations in urinary 17-OHCS excretion rates were correlated with reductions in catecholamine excretion in the urine (-.73) while increases in urinary catecholamines were associated with reduction in error rates with both low and medium Complex Counting task performance (-.78 and -.71 respectively).

Data collected during the first steaming day (Tables 5 and 7) show elevations in MSSS associated with increased emesis incidence (.92), increased anxiety (.78) and reductions in Critical Tracking (-.78) and Four-Letter Search (-.75) task performance.

Urine production increases were again associated with reductions in urine specific gravity (-.85) and urinary 17-OHCS values (-.75). Increased errors in low tone Complex Counting (.71) and increased times to complete the Spoke Control task (.78) were correlated with reductions in urine output.

Increased urine specific gravity values were associated with elevations in urinary 17-OHCS excretion (.91), increased anxiety (.89) and reductions in

error rates with low tone Complex Counting (-.76) and Spoke Control completion times (-.83).

Elevations in 17-OHCS excretion rates were significantly correlated with reductions in subject anxiety (-.92), Complex Counting errors with low tones (-.71) and Spoke Control task completion times (-.76).

Data collected during the second day of steaming (Tables 6 and 7) show elevations in MSSS scores were significantly correlated with emesis incidence (.97) and increased Spoke Control task completion times (.76). Increased emesis incidence was associated with increased Spoke Control completion times as well (.78).

Urine specific gravity values were associated with elevations in urinary excretion rates of 17-OHCS (.83) and higher rates in Navigation and Plotting performance (.75) while catecholamine excretion was correlated with Two-Letter Search performance (.73).

SUBJECT EXPERIMENT DEBRIEFING QUESTIONNAIRE

According to results obtained from test subject debriefing questionnaires (see Appendix C) 67% of the subjects felt that the rolling of the patrol boat affected their performance more than any other motion parameter. The remaining 33% attributed heaving motions to be the most detrimental to performance. Pitch was not considered to influence performance by any of the subjects.

Subjects reported that performance was affected least by pitch (66% of response) followed by roll (33%); no subject response was received with respect to heave motion. These data are shown in Table 12.

Questionnaire responses concerning the effects of vessel motion upon the subject's well being are summarized in Table 13. Roll was believed to be the most detrimental by 50% of the subjects followed by heave, 33%, and pitch, 17%.

Pitching motion was reported by 67% of the subjects as the motion which least affected their well being while the remaining response was evenly distributed between roll and heave motions.

TABLE 12. Subjects' Rating of the Motions Most and Least Detrimental to Performance

	Heave	Pitch	Roll
Most Detrimental	33%	0	67%
Least Detrimental	0%	66%	33%

TABLE 13. Subjects' Rating of the Motions Most and Least Detrimental to Well-Being

	Heave	Pitch	Roll
Most Detrimental	33%	17%	50%
Least Detrimental	16%	16%	67%

DISCUSSION

Prior to engaging in a discussion of the results obtained in this preliminary study the inherent limitations of the data must be reviewed. The experiment was designed to examine the direction and degree of changes in various performance, physiologial and affective state parameters brought about by exposure to, and relative changes in, vessel motions aboard a small monohull vessel. To investigate both direct and indirect influences of such motions, the test vessel steamed octagonal patterns which produced course changes of 45 degree increments with respect to that of the primary swell direction. If the sea spectra were constant within each day of steaming, and were equivalent between the two at sea days, then variables which were directly or indirectly influenced by vessel motions would show not only a consistent pattern within a given day (two octagons were repeated each day) but would be similar between steaming days if no significant habituation occurred.

Theoretically speaking, steaming an octagonal pattern in a consistent sea spectra would provide different motion environments for each octagonal leg. However, this simplified model of ocean dynamics doesn't include secondary or tertiary swells, wind shifts or other phenomena which may have contributed to perturbations in vessel response. Unfortunately, vessel motion and sea spectra measurement equipment could not be utilized for this preliminary study; therefore, no objective quantitative comparisons of either vessel motions or sea conditions can be made to confirm the stability of sea conditions or congruence of vessel motions from one octagonal pattern to the next.

The correlational analyses summarized in Tables 5, 6 and 7 also must be regarded as exploratory in nature. The relationships were obtained despite the offset testing intervals employed; thus, while task performance might have

degraded precipitously during a particular period in the steaming leg, the opportunity for the subject to indicate his mood or feeling of motion sickness might not have occurred for many minutes afterwards. Time-base changes are not addressed in this study, i.e. the correlations reported are all fixed in time. No attempts have been made to offset or adjust physiological or performance measures for their possible lag in response to vessel motion. Thus, the correlations obtained in this way are all the more remarkable. Other significant relationships may well exist if their appropriate time lag or phase relationships are factored into a comprehensive prediction equation. Additionally, those relationships which were observed may well be strengthened if the lag time response adjustments are made.

Finally, the results obtained in this preliminary study must be viewed as conservative, given the low sea state conditions (SS 2) during data collection, the use of experienced crewmen, and the possibility that strong learning effects occurred during repeated testing. Higher sea states, the absence of practice effects, and the lack of shipboard habituation would be expected to result in greater changes in the performance, physiology and affective state measures examined.

MOTION SICKNESS

If vessel motions directly influenced performance or physiological measures and sea state conditions were equivalent over steaming days, then a significant change from control (dockside) values and a consistent pattern associated with changes in the steaming course would be expected. Motion sickness provided the most dramatic result obtained from exposure to and changes in steaming course.

As expected, motion sickness symptomatology and the incidence of emesis significantly increased with the introduction of vessel motion. Motion

sickness symptomatology levels were not absent during the dockside control period due to the nature of the scoring procedure employed. Drowsiness, headache, and other minor symptoms associated with the motion sickness syndrome, were frequently reported by subjects during the eight hours of continuous performance testing. Hence, low symptomatology scores occurred during the dockside testing period when essentially no vessel motions were experienced.

Significant variations in symptomatology and emesis incidence were obtained in direct response to vessel course changes. Correlations between symptomatology levels for morning and afternoon octagons were significant (Day 1 $r = .75$; Day 2 $r = .63$; $p < .05$); and the correlation of symptomatology levels between steaming days was significant as well ($r = .70$, $p < .01$). Variations in the sea spectra and subject habituation to vessel motions within and between days may have prevented these correlations from being higher.

Although no quantitative information was obtained concerning the relationships between vessel motion and motion sickness, sufficient information exists to allow some general statements.

Motion sickness symptomatology severity and emesis incidence were consistently greater during octagonal steaming legs which possessed a head sea component (e.g. head or bow seas) than when the vessel was riding with the primary swell (e.g. stern or quartering seas) as shown by Figure 21. Steaming into the primary swell most likely increased the frequency and acceleration levels of the motions endured by the subjects; this would be particularly true of motions in the dimensions of heave and pitch. Such a finding lends support to previous vessel motion simulator research which argued that both frequency and acceleration characteristics of heave motions were related to motion sickness onset and severity (O'Hanlon and McCauley, 1974; McCauley et al., 1976).

It is unclear why such large differences were obtained between symptomatology levels and emesis incidence for steaming legs 3 and 7 when the vessel was steaming in opposite directions in the trough of the primary swell. Previous researchers have argued that a time lag exists between the onset and decay of motion sickness; such a theory helps explain the fact that motion sickness during leg 3 was always greater than leg 7 (McCauley et al., 1976; Kennedy, Personal Communication, 1978). It is also possible that a secondary swell was interacting with the primary swell to produce a more adverse motion environment during steaming leg 3. Without vessel motion recordings it is difficult to rule out or confirm either of these explanations. Furthermore, the lack of vessel motion data precludes definitive remarks regarding the role that particular dimensions of motion, or combinations thereof, may play in the onset or severity of motion sickness.

Motion sickness symptomatology severity (MSSS) scores were positively correlated with subject reports of fatigue during the control day ($r = .78$). It is not surprising that performing demanding tasks in a continuous and repetitive manner for eight hours led to subject reports of fatigue, headache, drowsiness and general discomfort. Such reports, which continued to increase with time during the control day, led to development of low MSSS scores concomitant with reports of fatigue.

Control day increases in MSSS scores were also associated with reductions in the number of attempts made with the Code Substitution task ($r = -.72$). Subjects performed a slightly fewer number of code substitutions as time progressed during the control day, probably due to fatigue onset, and reductions in motivation, which coincided with the mild increases in MSSS scores (see Figures 16 and 21).

During the first steaming day the periodic rise and fall of MSSS scores were significantly correlated with reductions in Critical Tracking ($r = -.78$), Four-Letter Search ($r = -.75$) and Code Substitution ($r = -.89$) performance; however, only the Critical Tracking Task's relationship to MSSS was consistent across both steaming days.

Spoke Control completion times were the only Spoke Test variable found to be significantly correlated with increased MSSS scores ($r = .76$). Although the correlation between MSSS and this reaction time task attained significance only on the second day of steaming, the correlation for the initial day of steaming approached statistical significance. Such findings suggest that this task may be sensitive to perturbations in subject motivation induced by variations in motion sickness severity.

The only variable which was consistently and significantly related to changes in subject MSSS each steaming day was that of emesis incidence ($r = .92$ and $r = .97$ for day 1 and day 2 respectively).

PHYSIOLOGICAL CORRELATES

Exposure to vessel motions which produced motion sickness led to distinctive reductions in urine production with concomitant increases in urine specific gravities and excretion rates of 17-hydroxycorticosteroids (17-OHCS). Catecholamine excretion rates increased significantly during the first day at sea; however, catecholamines in the urine were significantly reduced from control values during the second day of steaming. Changes in vessel motions associated with octagonal course changes, however, failed to produce significant variations in these measures.

The reductions in urine production seen with increasing severity of motion sickness in this study are consistent with previous laboratory studies reporting large elevations in serum ADH (24-fold) with concomitant oliguria

during coriolis-induced motion sickness (Eversmann et al., 1978; Taylor et al., 1957). Release of this neurohypophysial hormone reduces urine output by increasing the uptake of water in the collecting ducts of the kidneys. Such a reduction in free water diuresis promotes a concentration of urine constituents; hence, an elevation in urine specific gravity.

Although emesis can, and most likely did, contribute to such urinary changes observed, subjects who either did not vomit, or who vomited only during the last two hours of data collection, experienced pronounced oliguria and elevations in specific gravities as well. Furthermore, emesis was not significantly correlated with either urine production or specific gravity values.

If ADH release is sensitive to variations in motion sickness symptomatology severity or emesis incidence, one would expect to find significant congruence within each steaming day between urine production, or specific gravity, and indices of motion sickness. The lack of significant within day variations in these urine characteristics, given the cyclic behaviour of the motion sickness response, was not expected and undoubtedly contributed to the failure to develop parallels with correlation results found with MSSS and emesis scores. Several possible explanations exist for the lack of significant time based changes in urine production and specific gravity associated with transit of the steaming octagon. First, glucocorticoid levels were significantly elevated in response to the steaming environment. Elevations in these steroid levels may have promoted free water excretion by antagonizing the release of ADH from the neurohypophysis. Furthermore, glucocorticoids may have led to a higher urinary concentration of protein catabolic waste products produced via gluconeogenesis. A negative correlation obtained between 17-OHCS excretion rates and urine production on the first steaming

day tends to discount any major antagonism of ADH by increased glucocorticoid secretion. There was a strong correlation, however, between 17-OHCS excretion and increased urine specific gravity values across all three days of testing (control r = .92; at-sea 1 r = .91; at-sea 2 r = .82) which lends support for glucocorticoid confounding of the urine specific gravity response to motion sickness.

Second, catecholamine excretion rates were elevated on the first steaming day but then fell below control values on the second steaming day. Catecholamines can enhance the release of ADH as well as stimulate beta-adrenergic receptors in the renal distal tubules to reduce urine production and increase specific gravity. Increased catecholamine excretion rates were significantly correlated with increased urine production (r = .86); thus, this correlation, along with the inconsistent nonsignificant correlations obtained during the steaming days, argues against a strong influence of catecholamine secretion upon urinary characteristics in this study.

Third, the two-hour sampling of urine was taken after subjects were exposed to four specific octagonal legs (e.g., legs 1, 2, 3 and 4 or 5, 6, 7 and 8). Student *t*-test analyses of motion sickness symptomatology severity or emesis incidence related to octagonal halves revealed the most pronounced differences in these two indices of motion sickness to be with an octagonal split between legs 8, 1, 2, 3 and 4, 5, 6, 7. This offset between urine sampling and octagonal halves which produced the most divergence in motion sickness severity may have contributed to the lack of significant temporal variations.

Finally, although all of the above factors may have contributed to some degree to the lack of sensitivity of urine output or specific gravities to variations in motion sickness severity within steaming days, it is possible that quantum differences must be encountered in motion sickness severity

prior to observing statistically reliable concomitant variations in urinary characteristics with small subject populations (n = 6).

From these results, use of such renal measures as objective indices of motion sickness is warranted during the upcoming three vessel comparison study in which larger differences in motion sickness are predicted. The additional testing platforms are expected to produce subemesis levels of illness which should, when combined with cardiovascular and insensible water loss indices, provide a more accurate picture of the ADH response to motion sickness.

Catecholamine and 17-OHCS urinary excretion rates were significantly increased upon exposure to vessel motions during the first steaming day. On the second day of steaming, catecholamine excretion fell below the control day's level while 17-OHCS excretion rates remained elevated. The mean increase in excretion rates from control values for both hormones were consistent with the magnitude of elevations observed in previous investigations of motion sickness (Dahl et al., 1963; Evansmann et al., 1978; Habermann et al., 1978).

The lack of significant correlations for catecholamines or 17-OHCS and MSSS within steaming days, given the cyclic nature of motion sickness observed, was somewhat unexpected. There are factors which may account for this lack of significance.

The small subject population (n = 6) and the large individual differences observed in the data may have precluded determination of within day variations associated with motion sickness severity changes.

The stimulus response intervals for these hormones are generally long; varying between 30 minutes and two hours. Given the cyclic response within and between days for each of these hormones, it is possible that a time based adjustment would produce more reasonable correlations.

Variations in the force environment and subsequent degrees of motion sickness experienced between octagonal halves may not have been large enough in magnitude to induce significant changes in secretion rates of these paticular hormones. Additionally, without measures of the force environment, it is impossible to account for the confounding effects upon hormonal sensitivity to motion sickness brought about by varying postural demands.

As discussed earlier, catecholamines and glucocorticoids not only affect the ADH response to motion sickness but are capable of interacting within themselves. Increased secretion of epinephrine leads to enhanced release of ACTH which, in turn, serves to elevate glucocorticoid release. Concurrently, elevations in ADH secretion brought about by motion sickness or stress in general can produce elevations in ACTH levels. Elevations in ACTH secretion and subsequent release of glucocorticoids can reduce the demand for catecholamine secretion by suppressing the enzymatic degradation of the amines.

No correlations were found to substantiate the existence of most of these interrelationships; however, urine specific gravities, an indirect measure of ADH release, did correlate with elevations in urinary levels of 17-OHCS ($r = .91$ on at-sea day 1, $r = .83$ on at-sea day 2).

Finally, the urinary measures used in the present study do not afford the sensitivity to fluctuations in hormone release that serum values do. Thus, hormone secretion rates could have been co-varying with motion sickness, or vessel motion severity, while urinary excretion rates may have failed to reflect such changes.

Although no significant relationship was observed between changes in motion sickness severity and these stress hormones, it is clear there was considerable psychophysiological stress associated with exposure of habituated crewmen to the vessel motion environment.

PERFORMANCE MEASURES

Results from the analysis of variance (ANOVA) and interday comparisons using a Dunnett's -test show that exposure to vessel motion, or resultant motion sickness, led to a general decrement in almost all performance tasks measured during the first steaming day; however, only the number of attempts made with the Grammatical Reasoning and Single-Letter Search task along with Critical Tracking Task scores were degraded in a statistically signficant manner.

Scores obtained with exposure to the second day's vessel motion environment indicate there was a general improvement in task performance particularly with Grammatical Reasoning and Four-Letter Search performance. The non-significant decline in Navigation Plotting accuracy observed during the first day's steaming reached statistical significance during the second steaming day's exposure and was the only performance task to do so.

The general improvement in subject task performance from the control to final at-sea testing period indicates that, although extensive practice was provided on all tasks prior to experimentation, learning effects continued to occur and may have shrouded possible decrements in some performance tasks.

In addition to these learning or practice effects, habituation by the subjects to the vessel motion environment from steaming day 1 to steaming day 2 probably contributed to improved task performance on day 2.

Neither the introduction of vessel motion, nor resulting motion sickness, was able to disrupt alpha-numeric code substitution during the one and two minute test trials. Such findings indicate that regardless of the degree of motion sickness or biodynamic challenge to crewmen, their ability to perform some tasks for short periods of time is unaffected.

The introduction of vessel motion into the testing environment failed to produce significant between-days degradation in the two channel form of the Complex Counting Task; however, there were significant hourly variations in the number of absolute errors encountered with low tone monitoring. These variations throughout each testing day did not show any consistent associations with motion sickness or any other variable.

The fact that low tone channel monitoring performance produced significant variations in error rates within each day while the medium tone monitoring did not may be attributed to the higher performance frequency associated with the lower tone. With a larger number of low tones presented to the subject within the ten minute period, the opportunity to erroneously record or to omit a tone quartet was greater than for the less frequent medium tone stimulus. The absolute error rates between the two channels, however, were highly correlated ($r = .96$ $p < .01$).

These findings disagree with a previous investigation in which the Complex Counting task was used to investigate the influences of aircraft motion (Kennedy, et al., 1972). Kennedy's results indicate performance to degrade systematically with motions. There were a few differences between the studies which could explain the apparent discrepancy.

First, although the motion environments examined between the two studies cannot be compared, it is likely that the aircraft environment produced higher frequency and acceleration levels than were experienced aboard the patrol boat. Exposure to the different vibration spectra could have combined with the effects of air sickness to produce greater levels of fatigue than were experienced aboard the patrol boat.

Second, subjects in this study monitored only two channels; a significantly less demanding task than the three channel form of the test which was employed in the aircraft investigation.

Finally, due to a lack of recording equipment, subjects recorded tone quartets by making a pencil check on an answer sheet. Subjects were instructed not to count the number of quartet occurrences; however, it is possible that this mode of subject response provided a bias in the results obtained.

The results indicate the vessel motion environment does not interfere with the ability to sustain attention or to utilize short term memory during a ten-minute testing period; however, use of the three channel form of the Complex Counting task along with sophisticated recording equipment in the impending vessel class comparison should provide a clearer picture of vessel motion and motion sickness influences upon performance of this task.

Results obtained from the Spoke Test indicate vessel motion or motion sickness does not produce a statistically significant increase in the times required for subjects to make accurate spatial judgments or to perform a simple tapping task.

Significant correlations were obtained during the second day of steaming between Spoke Control times and indices of motion sickness while the first steaming day's correlations fell short of significance. Such findings indicate the motor component of the Spoke Test may be sensitive to either motion sickness itself or to the vessel motions occurring during the periods of increased MSSS and emesis. Without the vessel motion recordings it is difficult to assess the possible biodynamic and motion sickness interactions with this tapping task.

Vessel motion days when compared to the control day produced no pronounced effects upon either "experimental" or "difference" ("experimental" -"control") scores across days. Although "experimental" and "difference" scores varied significantly throughout the course of each day, no patterns were found between steaming days. Since these measures are thought to reflect aspects

of visual search, one must conclude that target location and recognition for short time periods in a limited visual field are not grossly affected by vessel motion. Performance changes occurring during the steaming days, however, may still reflect specific vessel motion interactions with visual search performance.

The first steaming day produced significant decrements in Single-Letter Search performance while Two and Four-Letter Search performance were not affected. There was a general improvement in all forms of the Letter Search task on the second steaming day with the improvement on the Four-Letter Search task reaching statistical significance ($p < .05$).

Theoretically speaking, if vessel motion or motion sickness were to interfere with letter target location in a complex visual display one would expect to see a reduction in the number of letter groups searched and elevation in the scan time per letter group. Furthermore, there should be a difference in letter group scan times for different numbers of target letters in unpracticed subjects (e.g., one-letter target scan times are shorter than for two-letter and two-letter target scan times shorter than for four-letter) with no difference in scan times between target sizes in practiced subjects. Results obtained, see Figure 12, show that two-letter target searches are associated with the fastest scan rates, followed by single-letter targets. Four-letter targets produced the longest scan periods per letter string.

Such results imply parallel processing of visual search information may have occurred at the two-letter target level. Parallel processing enables faster scan times than with serial search techniques. Four-letter target stimuli may have been too large to permit completely successful parallel

processing, or insufficient practice opportunity was available for our subjects to develop this strategy.

The large number of Letter Search task trials per day probably allowed subjects to improve either their serial or parallel processing search hierarchies across days; hence, the significant reduction in Four-Letter Search times.

Although vessel motions did produce difficulties during the first steaming day in visual recognition of target patterns within a complex visual background, the practice effects and possible changes in visual search hierarchies by subjects may have overwhelmed any vessel motion induced search degradation during the second steaming day.

Accuracy scores of the Navigation Plotting task were significantly reduced with exposure to vessel motion. This result occurred despite the restricted range of the test subject during the final days of the study. This performance decrement is consistent with results obtained by Sapov and Kuleshov, 1975, who found large reductions in the accuracy of complex operational tasks completed by experienced shipboard personnel.

In addition to the general reduction in accuracy, there were significant temporal variations in the subjects' performance during each day of testing. However, no differential temporal relationship was found within or between any of the three testing days.

Although exposure to the vessel motion environment led to a decline in Navigation Plotting accuracy, changes in vessel motion characteristics or in motion sickness severity may not have been directly responsible for the observed decrement. This statement is substantiatied by the lack of significant correlations between accuracy scores and indices of motion sickness as well as congruence in scores between steaming days. It is possible that a phase shift relationship exists between these and other variables with

motion sickness, as suggested by McCauley, et al., 1976, which would account for the lack of correlations.

The Navigation Plotting task differed from the others tasks examined in this study in many ways which could account for its prominent decrement associated with vessel motion exposure. First, the task was completely self-paced. Second, the task was the most complex of all performance measures examined in that it required the use and integration of many skills rather than relying upon a single performance modality. Finally, the task was relatively long in duration (9 minutes) when compared to the simple tasks which required from 20 seconds to several minutes at most.

The above factors would argue that accurate performance in the Navigation and Plotting task would be sensitive to changes in subject motivation. Birren, 1949, argued that as long as performance task demands were simple and of short duration they would be relatively insensitive to the influences of motion sickness; however, he speculated that any complex task requiring a substantial amount of time would suffer with the onset of sickness. Birren's argument appears to have some basis for the lack of impact of motion sickness upon only "maintenance" forms of performance, which rely more highly upon sustained crew motivation than "peak" or short term forms of performance. Unfortunately, as stated earlier, there was no significant relationship indicated in correlation analyses between symptomatology levels and Navigation Plotting performance. The lack of significant relationships may be due to a confounding contribution of biodynamic interference in plotting tool manipulation brought about by vessel motions and stimulus response lags previously mentioned.

It is likely that both the vessel dynamics as well as motion sickness severity play a role in the degradation of Navigation Plotting accuracy;

however, without accurate measures of the dynamic environment it is impossible to assess these multivariate contributions.

AFFECTIVE STATE

Analysis of mood adjective checklist data indicates that exposure to vessel motion led to significant increases in subject's reports of fatigue ($p < .01$). Fatigue was not found to vary with octagonal steaming leg transit nor with motion sickness severity; hence, elevation in subject fatigue levels during steaming days appears to reflect the increased postural demands induced by vessel motion rather than motion sickness severity.

No other dimensions of affective state (e.g., anxiety, aggression, vigor, elation, egotism, sadness, surgency, concentration or skepticism) changed significantly with the introduction of vessel motion. Subject reports of concentration and skepticism did vary with octagonal steaming leg; however, only concentration showed a systematic hourly fluctuation between steaming days ($r = .74$; $p < .05$).

No significant correlations were obtained between changes in either subject reports of concentration or skepticism and indices of motion sickness.

Although anxiety scores, as shown in Figure 20, were elevated during octagonal steaming legs with head sea components for both steaming days, these elevations failed to reach statistical significance. Increase anxiety reports were generally correlated with motion sickness indices such as MSSS, emesis incidence and urinary indices of ADH. Additionally, anxiety was correlated negatively with performance on CTT, Four-Letter Search, Spoke Control and Code Substitution during the first day at sea.

It thus appears that experienced crewmen who are familiar with the vessel motion environment and the motion sickness syndrome do not suffer significant perturbations in a majority of mood dimensions during motion sickness or vessel motion exposure. Fatigue levels do increase in a significant manner with exposure to vessel motions aboard the WPB, but these increases are mainly attributed to increased postural maintenance demands. Subject concentration as well as skepticism may also suffer when sea states are increased above that observed in this preliminary study.

CONCLUSIONS

Conduct of this preliminary study demonstrated the proposed experimental paradigm to be acceptable, with a few modifications, for use in the impending multiple vessel comparisons. Furthermore, analysis of the data collected provided preliminary indications of the sensitivity of a variety of performance tasks, physiological stress and affective state dimensional indices of experienced crewmen subjected to motions aboard a small monohull vessel in low sea states.

All physiological indices of crew stress or motion sickness were dramatically influenced with the introduction of vessel motion. Motion sickness severity was found to rise and fall depending upon the encounter direction of the vessel to the movement of the primary swell; steaming courses with head or bow seas produced significantly greater degrees of illness than did courses possessing stern or quartering seas.

Although pronounced oliguria and increased urine specific gravities were found during exposure to the vessel motion environment, sensitivity of these indirect measures of ADH response was not good with minor differences in motion sickness severity. The sampling method does have advantages over invasive techniques in long term repetitive studies in that performance tasks are not perturbed, subject stress associated with invasive sampling is avoided and subject acceptance of total void urine collection is good. Use of such measures in a multiple vessel class comparison, in which quantum differences in kinetosis are expected, remains warranted.

Vessel motion, or concomitant motion sickness, clearly produces a state of psychophysiological stress in experienced crewmen. Catecholamines and 17-hydroxycorticosteroids (17-OHCS), biochemical indicants of stress, were both

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markedly elevated during the first steaming day with 17-OHCS elevations sustained during the second day of steaming. Use of such indices of vessel motion-induced stress may be discriminating in the following vessel class comparisons.

Along with the physiological response observed during vessel motion, some dimensions of crew affective states were altered. The only significant mood change reported with the introduction of the steaming periods was that of fatigue. Fatigue elevation during steaming periods is attributed to increased postural and metabolic demands associated with the vessel motions themselves rather than motion sickness; reports of fatigue failed to show congruence with any indice of motion sickness.

Although significant daily temporal variations were observed with subject reports of concentration and skepticism, only concentration showed any consistent pattern between steaming days ($r = .74$, $p < .05$). It is difficult to make judgments regarding the cause of these fluctuations for no informative correlations were obtained betweeen these two mood dimensions and other reasonable factors such as MSSS. Thus, it appears that no significant mood swings occur, with the exception of fatigue and possibly concentration, during vessel motion exposure in experienced crewmen who are familiar with the rigors of both vessel motion and motion sickness.

Results obtained from performance tests administered indicate that some but not all performance is degraded during exposure to vessel motion or motion sickness. The ability of crewmen to perform arithmetic calculations, use plotting instruments and interpret nomograms in an accurate manner during the Navigation Plotting task was degraded when the vessel was underway. Additionally, visual search performance was hampered in the Single-Letter task indicating the ability of crewmen to detect a familiar target within a complex visual background suffers in vessel motion environments which provoke motion sickness.

Such findings are remarkable given the strong learning effects observed with most of the tasks studied during this experiment. Tasks such as Grammatical Reasoning, Code Substitution, Critical Tracking, Spoke Test and Complex Counting, although showing some decrement during the initial day of steaming, continued to improve throughout the study. It is possible that the lack of stabilized subject performance, and decrement associated with biodynamic or physiologic interference introduced with vessel motions, could have clouded the results.

As stated previously, Russian scientists found every form of operational performance investigated to degrade with exposure to vessel motions while all previous vessel motion simulator studies had argued against any such influence. Results from this study lend support to the position that crew performance is affected by vessel motion, or motion sickness, but that not all types of performance are necessarily degraded at sea.

Why such discrepancies in crew or subject performance exist between real world and simulated vessel motion environments remains a mystery at this point. Possibly the psychological posture between subjects in real world studies and subjects in vessel motion simulator studies is different; subjects aboard vessel motion simulators may leave the noxious environment at any time while subjects aboard steaming vessels must remain aboard whether they participate in the experiment or not. Such situations may promote olympian efforts during simulations in which experiment termination can be immediate, while shipboard subjects may have to temper or conserve their efforts to sustain an "acceptable" level of performance throughout the day.

Learning effects, or the lack of performance task stability, during previous simulator studies may also have contributed to the lack of performance decrements; the Russian study examined highly practiced daily operational

tasks which should have been very stable measures.

Hopefully, use of vessel motion and sea spectra recordings, and more intensified pre-experimental training in the various performance tasks, will enable definition of particular vessel motion frequencies and accelerations responsible for motion sickness onset, physiological and psychological stress and the ultimate concern; that of crew performance degradation.

Further analyses of vessel motion influences upon crewmen are required to provide proper vessel design criteria for future vessels, establish ship stabilization objectives from crew habitability and performance standpoint for existing vessels, and to provide recommendations for ship handling tactics to maximize crew performance at sea.

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APPENDICES

APPENDIX A

PRE-SELECTION QUESTIONNAIRE

APPENDIX A

PRESELECTION QUESTIONNAIRE

INSTRUCTIONS

The enclosed questionnaire has been provided in order to obtain some essential information concerning certain physical characteristics you may possess. This information will be used to help us select a representative group of test subjects for participation in the previously discussed study.

Crewmen selected as tentative candidates for participation in the sea trials will be notified within one week. At that time a more detailed description of performance measures will be presented. Demonstrations and practice sessions will be given during the more detailed briefing as well.

Strict confidentiality will apply to all information acquired in the questionnaire and only those associated with the USCG Ship Motion Research Team will have access to the information provided.

Date: ___________

CGD14 SEA TRIALS HUMAN FACTORS
SELECTION QUESTIONNAIRE

Name: ______________________ Age: ______ Sex: ______

Rate/Rank: ______________________ Married: ______ Single: ______

Unit: ______________________ Height: ______ Wt: ______

1. Have you ever participated in an experiment before?

   YES ____ NO ____ When? ______________________

2. Number of months spent onboard your present ship: ________

3. Total shipboard experience excluding your present ship:

   Ship type __________ Time onboard in months ________

   __________ ________

   __________ ________

4. Have you ever been seasick? YES ____ NO ____. If YES, would you describe the experience. Please describe weather conditions, length of voyage, type of vessel, whether you recovered while at sea, (and if you became sick again), and any other factors you consider pertinent.

5. From your experience at sea would you say that you:

   Always get sick ____ Frequently get sick ____ Sometimes ____

   Rarely ____ Never ____

6. Have you ever been motion sick under any conditions other than at sea?

   YES ____ NO ____ If so, under what conditions?

7. If you vomited while experiencing motion sickness, did you:

   Feel better and remain so? ______________________

   Feel better temporarily, then vomit again? ______________

   Feel no better, but not vomit again? ________________

   Feel no better and continued to vomit repeatedly? ________

8. In general, how susceptible to motion sickness are you?

   Extremely ____ Very ____ Moderately ____ Minimally ____ Not at all ____

Name: ______________________________

9. In the past 8 weeks have you been nauseated FOR ANY REASON?

NO _____ YES _____. If YES, explain: ____________________

10. In the past when you were nauseated for any reason, did you:

Vomit easily _____ Vomit only with difficulty _____ Retch and finally vomit with great difficulty _____ Could never vomit when nauseated _____ Never nauseated in life _____.

11. Have you ever vomited in your sleep after heavy partying on the previous night? YES _____ NO _____

12. What do you think your chances of getting sick would be in an experiment where 50% of the subjects get sick?

I almost certainly would __________
I probably would __________
I probably would not __________
I almost certainly would not __________

13. Most people experience faintness (not as a result of motion) 2 or 3 times a year. During the past year you have felt faint:

More than this __________

The same as this __________

Less than this __________

Never faint __________

14. How well do you understand your motives and reasons for doing things?

Very well __________

Better than most __________

About average __________

Less than average __________

Not well at all __________

15. Have you ever had an ear illness or injury which was accompanied by dizziness and/or nausea?

16. Were you a controller of a vehicle when you were motion sick?

17. Would you volunteer for an experiment where you knew that:

85% of the people became seasick? YES _____ NO _____

50% of the people became seasick? YES _____ NO _____

25% of the people became seasick? YES _____ NO _____

0% of the people became seasick? YES _____ NO _____

Name: ______________________________

18. What was the highest level of education you have attained?

Eighth grade _________

High School _________

Two years in college _________

Four years in college _________

Graduate school _________

19. Most people experience slight dizziness (not as a result of motion) 3 to 5 times a year. The past year you have been dizzy:

More than this _________

The same as _________

Less than _________

Never dizzy _________

20. When you become motion sick what type of remedy do you use? (Medical or otherwise)

21. How concerned are you with your performance on:

School exams:	Very great _____	Great _____	Moderate _____	Little _____
Shipboard Performance:	_____	_____	_____	_____
Sporting Activities:	_____	_____	_____	_____

22. Do you normally expect to perform better _____, same as _____, or worse than _____ the average person?

23. Do you smoke daily _____, infrequently _____, or never _____?

24. Do you drink alcohol daily _____, heavily at infrequent times _____, lightly at infrequent times _____, rarely _____, never _____

25. Do you frequently take medications or drugs?

NO _____ YES _____ (If YES, do not specify at this time)

26. Have you been ill in the past year? NO _____ YES _____. If YES, specify: severity, time course and locality (on body).

27. I am _____ am not _____ in my usual state of fitness.

APPENDIX B

CGD14 SEA TRIALS HUMAN FACTORS

APPENDIX B

CGD14 SEA TRIALS HUMAN FACTORS

TEST SUBJECT CONSENT FORM

I, ______________________ having attained my 18th birthday, and otherwise having full capacity to consent, do hereby volunteer to participate in an investigation entitled, "CGD14 SEA TRIALS HUMAN FACTORS ANALYSIS," under the direction of LTjg Steven F. Wiker USCGR.

The implications of my voluntary participation; the nature, duration, and purpose; the methods and means by which it is to be conducted; and the inconveniences and hazards to be expected have been thoroughly explained to me by LTjg Wiker, and are set forth in full on the reverse side of this Agreement, which I have initialed. I have been given an opportunity to ask questions concerning this investigation study, and any such questions have been answered to my full and complete satisfaction.

I understand that I may at any time during the course of this investigation study revoke my consent and withdraw from the study without prejudice, however, I may be required to undergo certain further examinations if, in the opinion of LTjg Wiker, such examinations are necessary for my health or well being.

______________________________ __________
Signature Date

I was present during the explanation referred to above, as well as the Volunteer's opportunity for questions, and hereby witness his signature.

______________________________ __________
Signature of Witness Date

I understand that I will be performing an array of cognitive and perceptual-psychomotor tasks while at dockside and at sea for a period of one week in mid April. __________

During this study I will be giving urine samples for analysis of stress hormones and specific gravities. __________

I understand that I will have surface electrodes attached to my chest during the study for monitoring my electrocardiogram (EKG). __________

I realize that there is a possibility that I may become seasick during the days in which we are steaming at sea. __________

I am aware that my diet and liberty hours will be strictly controlled and that during dockside and at sea trials my liberty will be curtailed. __________

I am aware that the purpose of this study is to gather important data on the effects of vessel motion, in different sea states, upon crew performance and well being. __________

APPENDIX C

CGD14 SEA TRIALS HUMAN FACTORS POSTEXPERIMENTAL DEBRIEFING

Date:__________________

APPENDIX C

CGD14 SEA TRIALS HUMAN FACTORS
POSTEXPERIMENTAL DEBRIEFING

Subject No.______ Name:____________________

1. Were you assigned or did you volunteer to serve in this experiment?

   Assigned_____ Volunteered_____ Why?____________________

   ____

2. Which ship motions (roll, pitch, or heave) affected your task performance most and least?

   Most____________________ Least____________________

4. Were you sick at any time during the experiment?

   No_____ Yes_____ If yes, were the experimenters aware that you were sick every time you got sick? Yes_____ No_____

5. Did you report each sickness or note it in your log sheets? Yes_____ No_____

6. What was the most meaningful task?____________________

7. What was the least meaningful task?____________________

8. What was the most difficult task?____________________

9. What was the least difficult task?____________________

10. What task did you like the best?____________________

11. What task did you like least?____________________

12. If given the chance, would you serve again in this experiment? No_____ Yes_____

    Why?____________________

    Why not?____________________

13. What would you do to improve the experiment?____________________

    ____

14. What physiological sampling technique was most bothersome?____________________

    ____

15. What physiological sampling technique was least bothersome?____________________

    ____

Name: ______________________________

16. How would you improve upon the physiological sampling techniques?

17. Which adjectives on the check list were most difficult to make decisions about? (Place in order of difficulty)

1 ____________ 2 ____________ 3 ____________ 4 ____________

18. Which adjectives on the check list were least difficult to make decisions about? (Place in order of ease)

1 ____________ 2 ____________ 3 ____________ 4 ____________

19. How would you improve upon the check list?

20. On which vessel do you think you performed best? (Rank order)

1 ____________ 2 ____________ 3 ____________

21. On which vessel did you feel best? (Rank order)

1 ____________ 2 ____________ 3 ____________

APPENDIX D

SOUND LEVEL RECORDINGS IN TEST COMPARTMENT

APPENDIX D

SOUND LEVEL RECORDINGS IN TEST COMPARTMENT

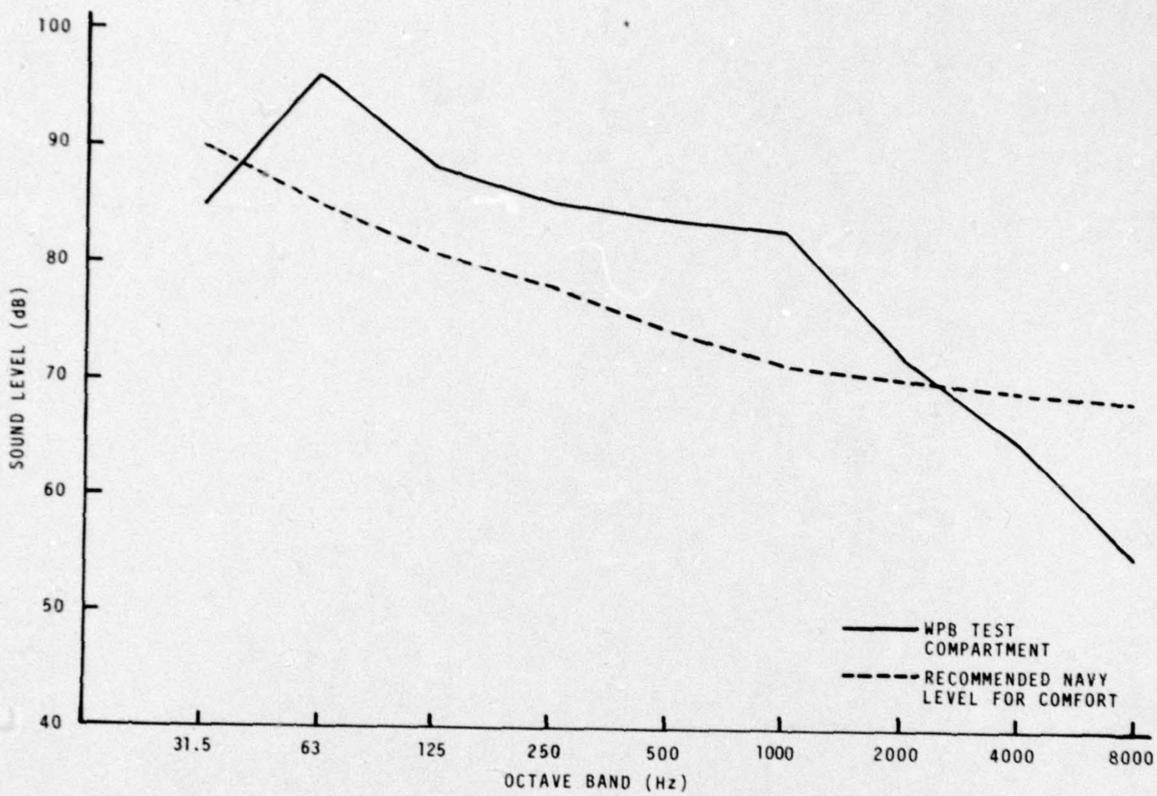

Figure D-1. Sound levels in WPB test compartment

APPENDIX E

TEMPERATURE AND HUMIDITY PLOTS

APPENDIX E

TEMPERATURE AND HUMIDITY PLOTS

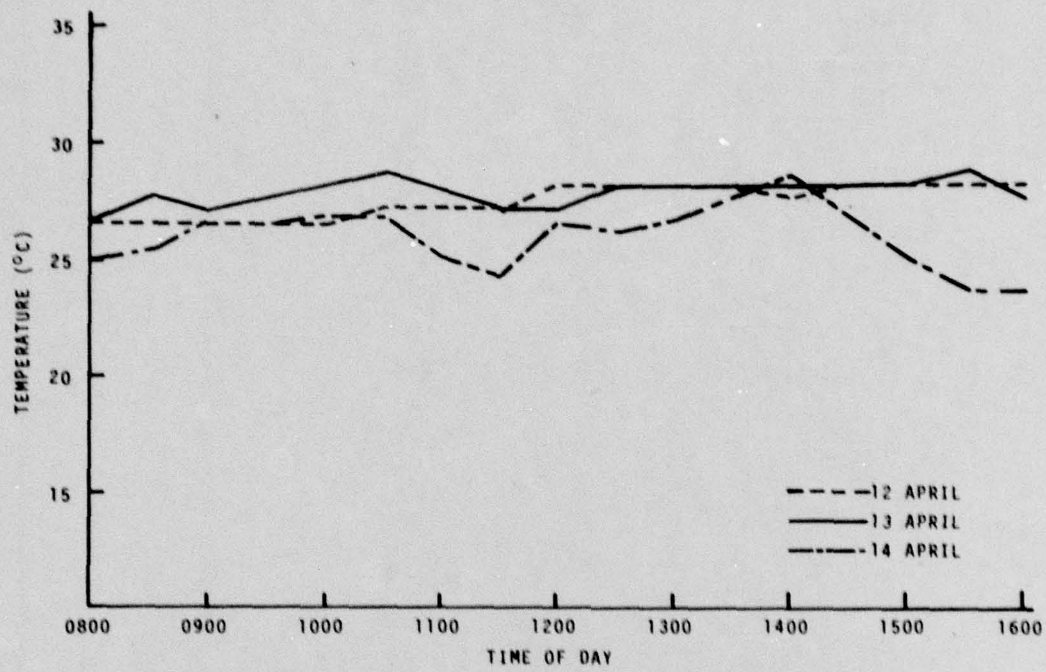

Figure E-1. Testing Compartment temperature

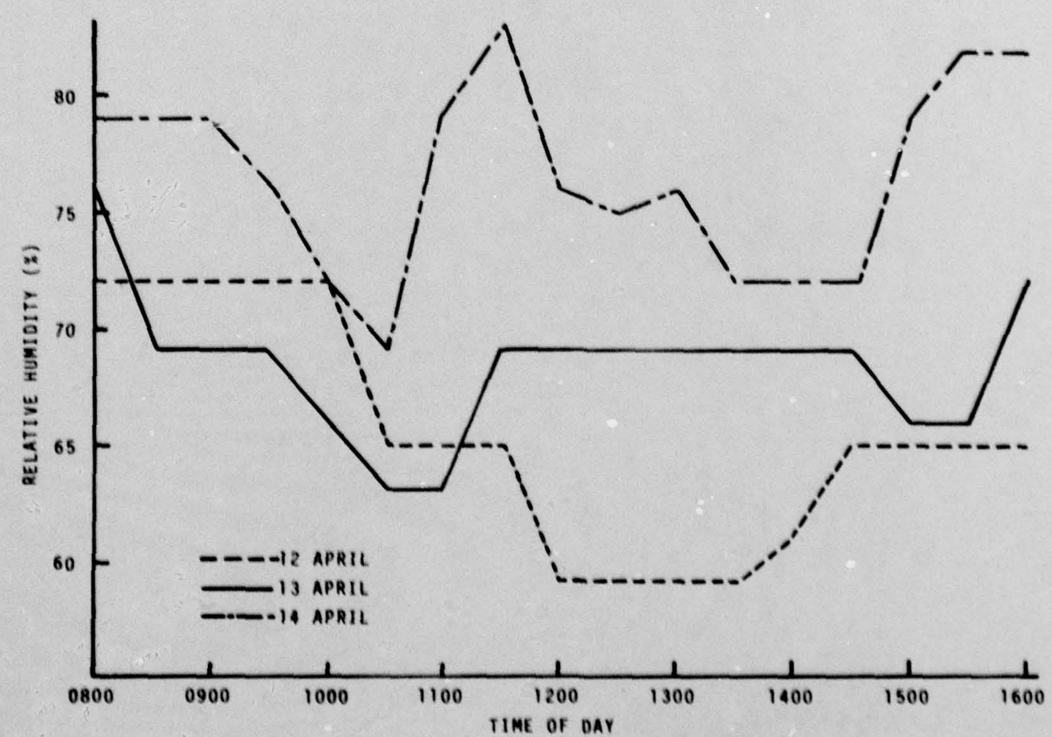

Figure E-2. Testing Compartment humidity

APPENDIX F

MOOD AND MOTION SICKNESS QUESTIONNAIRE

APPENDIX F

MOOD AND MOTION SICKNESS QUESTIONNAIRE

DATE________________________ SUBJECT______________________________

WATCH______________________________

MOOD AND MOTION QUESTIONNAIRE

Mood Questionnaire

1. angry Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

2. clutched up Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

3. carefree Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

4. elated Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

5. concentrating Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

6. drowsy Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

7. affectionate Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

8. regretful Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

9. dubious Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

10. boastful Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

11. active Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

12. defiant Definitely_____ Slightly_____ Undecided_____
Definitely NOT_____ Remarks_____________________

MOOD AND MOTION QUESTIONNAIRE

13. fearful Definitely____Slighly____Undecided____
Definitely NOT____Remarks____________

14. playful Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

15. overjoyed Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

16. engaged in thought Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

17. sluggish Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

18. kindly Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

19. sad Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

20. skeptical Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

21. egotistic Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

22. energetic Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

23. rebellious Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

24. jittery Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

25. witty Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

26. pleased Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

27. intent Definitely____Slightly____Undecided____
Definitely NOT____Remarks____________

MOOD AND MOTION QUESTIONNAIRE

28. tired — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

29. warmhearted — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

30. sorry — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

31. suspicious — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

32. self-centered — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

33. vigorous — Definitely_____ Slightly_____ Undecided_____ Definitely NOT_____ Remarks____________________

Motion Questionnaire

1. general discomfort — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

2. fatigue — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

3. boredom — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

4. mental depression — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

5. drowsiness — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

6. headache — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

7. "fullness of the head" — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

8. blurred vision — None_____ Slight_____ Moderate_____ Severe_____ Remarks____________________

MOOD AND MOTION QUESTIONNAIRE

9. a. dizziness with eyes open None____ Slight____ Moderate____ Severe____
Remarks________________________________

b. dizziness with eyes closed None____ Slight____ Moderate____ Severe____
Remarks________________________________

10. loss of direction None____ Slight____ Moderate____ Severe____
Remarks________________________________

11. a. salivation increased None____ Slight____ Moderate____ Severe____
Remarks________________________________

b. salivation decreased None____ Slight____ Moderate____ Severe____
Remarks________________________________

12. sweating None____ Slight____ Moderate____ Severe____
Remarks________________________________

13. faintness None____ Slight____ Moderate____ Severe____
Remarks________________________________

14. aware of breathing None____ Slight____ Moderate____ Severe____
Remarks________________________________

15. stomach upset None____ Slight____ Moderate____ Severe____
Remarks________________________________

16. nausea None____ Slight____ Moderate____ Severe____
Remarks________________________________

17. burping None____ Slight____ Moderate____ Severe____
Remarks________________________________

18. loss of appetite None____ Slight____ Moderate____ Severe____
Remarks________________________________

19. increased appetite None____ Slight____ Moderate____ Severe____
Remarks________________________________

20. desire to move bowels None____ Slight____ Moderate____ Severe____
Remarks________________________________

21. vomiting None____ Slight____ Moderate____ Severe____
Remarks________________________________

MOOD AND MOTION QUESTIONNAIRE

22.	confusion	None____ Slight____ Moderate____ Severe____ Remarks________________
23.	apathetic	None____ Slight____ Moderate____ Severe____ Remarks________________
24.	queasy	Yes____ No____ Remarks________________
25.	relaxed	Yes____ No____ Remarks________________
26.	clammy	Yes____ No____ Remarks________________
27.	yawning	Often____ Occasionally____ None____ Remarks________________
28.	smoking more than usual	Yes____ No____ Remarks________________
29.	physically tired	Very____ Somewhat____ No____ Remarks________________
30.	mentally tired	Very____ Somewhat____ No____ Remarks________________
31.	crave certain foods	Yes____ No____ Type________________
32.	claustrophobic	Yes____ No____ Remarks________________
33.	bothered by personal habits of partner	Yes____ No____ Remarks________________
34.	irritable	Very____ Somewhat____ No____ Remarks________________

APPENDIX G

DEFINITIONS OF SEA CONDITIONS: WAVE AND SEA FOR FULLY ARISEN SEA

APPENDIX G

DEFINITIONS OF SEA CONDITIONS: WAVE AND SEA FOR FULLY ARISEN SEA**

Sea—General		Wind				Sea								
Sea State	Description	(Beaufort) Wind force	Description	Range (knots)	Wind Velocity (knots)	Wave Height: Average	Wave Height: Significant	Wave Height: Average of One-Tenth Highest	Significant Range Periods [sec]	Periods of maximum Energy of Spectra $T_{max} = T_c$	Average Period $\bar{T}_s$	Average Wave-length $\bar{L}_w$ [ft unless otherwise indicated]	Minimum Fetch (nautical miles)	Minimum Duration [hr unless otherwise indicated]
	Sea like a mirror	U	Calm	1	0	0	0	0	—	—	—	—	—	—
0	Ripples with the appearance of scales are formed, but without foam crests.	1	Light airs	1–3	2	0.04	0.01 0.01	0.09	1.2	0.75	0.5	10 in	5	18 min
1	Small wavelets; short but pronounced crests have a glossy appearance, but do not break.	2	Light breeze	4–6	5	0.3	0.5	0.6	0.4–2.8	1.9	1.3	6.7 ft	8	39 min
	Large wavelets; crests begin to break. Foam of glossy appearance. Perhaps scattered with horses.	3	Gentle breeze	7–10	8.5	0.8	1.3	1.6	0.8–5.0	3.2	2.3	20	9.8	1.7
					10	1.1	1.8	2.3	1.0–6.0	3.2	2.7	27	10	2.4
2	Small waves, becoming larger; fairly frequent white horses.	4	Moderate breeze	11–16	12	1.6	2.6	3.3	1.0–7.0	4.5	3.2	40	18	3.8
					13.5	2.1	3.3	4.2	1.4–7.6	5.1	3.6	52	24	4.8
					14	2.3	3.6	4.6	1.5–7.8	5.3	3.8	59	28	5.2
3					16	2.9	4.7	6.0	2.0–8.8	6.0	4.3	71	40	6.6
4	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray).	5	Fresh breeze	17–21	18	3.7	5.9	7.5	2.5–10.0	6.8	4.8	90	55	8.3
					19	4.1	6.6	8.4	2.8–10.6	7.2	5.1	99	65	9.2
					20	4.6	7.3	9.3	3.0–11.1	7.5	5.4	111	75	10
5	Large waves begin to form; white crests are more extensive everywhere (probably some spray).	6	Strong breeze	22–27	22	5.5	8.8	11.2	3.4–12.2	8.3	5.9	134	100	12
					24	6.6	10.5	13.3	3.7–13.5	9.0	6.4	160	130	14
					24.5	6.8	10.9	13.8	3.8–13.6	9.2	6.6	164	140	15
6					26	7.7	12.3	15.6	4.0–14.5	9.8	7.0	188	180	17
	Sea heaps up, and white foam from breaking waves being to be blown in streaks along the direction of the wind (Spindrift begins to be seen).	7	Moderate gale	28–33	28	8.9	14.3	18.2	4.5–15.5	10.6	7.5	212	230	20
					30	10.3	16.4	20.8	4.7–16.7	11.3	8.0	250	280	23
					30.5	10.6	16.9	21.5	4.8–17.0	11.5	8.2	258	290	24
7					32	11.6	18.6	23.6	5.0–17.5	12.1	8.6	285	340	27
7	Moderate high waves of greater length; edges of crests break into spindrift. The form is blown in well-marked streaks along the direction of the wind. Spray affects visibility.	8	Fresh gale	34–40	34	13.1	21.0	26.7	5.5–18.5	12.8	9.1	322	420	30
					36	14.8	23.6	30.0	5.8–19.7	13.6	9.6	363	500	34
					37	15.6	24.9	31.6	6–20.5	13.9	9.9	376	530	37
					38	16.4	26.3	33.4	6.2–20.8	14.3	10.2	392	600	38
					40	18.2	29.1	37.0	6.5–21.7	15.1	10.7	444	710	42
8	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Visibility affected.	9	Strong gale	41–37	42	20.1	32.1	40.8	7–23	15.8	11.3	492	830	47
					44	22.0	35.2	44.7	7–24.2	16.6	11.8	534	960	52
					46	24.1	38.5	48.9	7–25	17.3	12.3	590	1110	57
	Very high waves with long overhanging crests. The resulting foam is in great patches and is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The rolling of the sea becomes heavy and shocklike. Visibility is affected.	10	Whole* gale	48–55	40	26.2	41.9	53.2	7–5–26	18.1	12.9	650	1250	63
					50	28.4	45.5	57.8	7–5.27	18.8	13.4	700	1420	69
					51.5	30.2	48.3	61.3	8–28.2	19.4	13.8	736	1560	73
					52	30.8	49.2	6.25	8–28.5	19.6	13.9	750	1610	75
9					54	33.2	53.1	67.4	8–29.5	20.4	14.5	810	1800	81
	Exceptionally high waves. Sea completely covered with long white patches of foam lying in direction of wind. Everywhere edges of wave crests are blown into froth. Visibility affected.	11	Storm*	56–63	56	35.7	57.1	72.5	8.5–31	21.1	15	910	2100	88
					59.5	40.3	64.4	81.8	10–32	22.4	15.9	985	2500	101
	Air filled with foam and spray. Sea white with driving spray. Visibility very seriously affected.	12	Hurricane*	64–71	> 64	> 46.6	74.5	94.6	10–35	24.1	17.2	—	—	—

* For hurricane winds (and often whole gale and storm winds) required durations and reports are barely attained. Seas are therefore not fully arisen.

† Revised December 1964 by L. Moskowitz and W. Pierson. Used courtesy of The Navy Oceanographic Office.